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JOURNAL *of* ECONOMIC ENTOMOLOGY

Formerly Published by the
AMERICAN ASSOCIATION OF ECONOMIC ENTOMOLOGISTS

Published by the
ENTOMOLOGICAL SOCIETY OF AMERICA
Formed in 1953 by Consolidation of the
American Association of Economic Entomologists
(1889-1952)
and the former
Entomological Society of America (1906-1952)
MENASHA, WISCONSIN

DECEMBER • 1953

Volume 46 Number 6

JOURNAL OF ECONOMIC ENTOMOLOGY

Published by
ENTOMOLOGICAL SOCIETY OF AMERICA
AT MENASHA, WISCONSIN

F. W. Poos, Editor, *pro tempore*, Beltsville, Md.

ASHLEY B. GURNEY, *Executive Secretary*, 1530 P. St., N.W., Washington 5, D.C.

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A bimonthly journal published on the 15th of February, April, June, August, October and December, devoted to the interests of economic entomology and publishing the official notices and proceedings of the Entomological Society of America.

TERMS OF SUBSCRIPTION. To members of the Entomological Society of America in continental U.S.A. and its possessions $4.00. Members outside of the U.S.A.—$4.50. Non-members in the U.S.A., Cuba, Mexico and Canada—$10.00. Non-members in other countries—$10.00 plus 60¢ postage. Single copies $1.75 plus postage of 10¢ per copy.

BUSINESS COMMUNICATIONS of the Society and SUBSCRIPTIONS AND ADVERTISEMENTS to the Journal should be sent to the Executive Secretary, Ashley B. Gurney, 1530 P. St., N.W., Washington 5, D.C.

MANUSCRIPTS and other copy for the Journal as well as all correspondence concerning Journal content, should be addressed to the editor *pro tempore*, F. W. Poos, Agricultural Research Center, Beltsville, Maryland.

CHANGE OF ADDRESS must reach the office of the Executive Secretary 45 days prior to the month of issue to be effective for that month.

Entered as second class matter at the Post Office at Menasha, Wisconsin. Acceptance for mailing at special rate of postage under the provisions of Sec. 34.40, Par. (D), provided for in the Act of February 28, 1925, embodied in paragraph 4, Section 538, P. L. and R., authorized May 1, 1936

Printed in U.S.A.

ISSUED MARCH 10, 1954

JOURNAL OF ECONOMIC ENTOMOLOGY
ENTOMOLOGICAL SOCIETY OF AMERICA
Formerly Official Organ American Association of Economic Entomologists

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ANNOUNCEMENTS

ASHLEY B. GURNEY APPOINTED EXECUTIVE SECRETARY

On December 5, 1953, meeting at Los Angeles, the Interim Governing Board appointed Dr. Ashley B. Gurney to the post of Executive Secretary of the Entomological Society of America, effective January 1, 1954. Dr. Gurney, born in Cummington, Massachusetts, received his entomological training at the University of Massachusetts, obtaining the Ph.D. degree there in 1940 studying with Dr. C. P. Alexander. In 1935–36 he engaged in graduate study at the University of Minnesota and worked with Dr. W. A. Riley. Since 1936 he has been with the Division of Insect Detection and Identification, BEPQ., at Washington, D. C., except for military service as Entomologist in the Sanitary Corps, United States Army, from 1942 to 1946. Dr. Gurney has been active in the past in both parent organizations of the new Society, and brings with him the firm expressed belief that the new organization will be an effective tool to serve the entire profession of entomology. The Governing Board wishes to express its best wishes to Dr. Gurney in his new position and urges the entire membership to support him whole-heartedly.

H. H. Ross

NEW EDITION OF ENTOMA

The 10th Edition of Entoma, a Directory of Entomological Services, Entomological Organizations, and Pest Control Products, is now ready for distribution. This is a special biennial publication of the Entomological Society of America.

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A free copy will be sent to each member of the Society who requests it and either remits 50 cents for handling costs or authorizes adding that sum to his Society account for inclusion in the next annual bill. This handling charge was authorized by the Interim Governing Board.

Address orders and other correspondence to:

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NOTE OF APPRECIATION

To our friends who contributed to the fund for the watches and citations that were presented on our retirement from active participation in the affairs of the American Association of Economic Entomologists, we wish to convey our sincere thanks.

L. M. Peairs and Ernest N. Cory

ERRATA

Authors have requested the following corrections in Vol. 46, No. 2:

Page 256, Column 1: Delete sentence beginning with line 23.

Page 257: In Literature Cited the order of the references cited (1) and (2) should be reversed, and the second reference as published should read Public Health Monograph No. 6, instead of Public Health Reports No. 6.

Page 287, Scientific Note, Column 2, line 2: substitute "newly" for "nearly."

Page 287, Column 2, last line—add 210.

JOURNAL OF ECONOMIC ENTOMOLOGY
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Vol. 46 December, 1953 No. 6

Calcium Carbonate as a Diluent for Insecticide Dusts[1]

C. F. RAINWATER, E. W. DUNNAM, E. E. IVY, and A. L. SCALES, *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*

It has been generally assumed that most organic insecticides are incompatible with calcium carbonate. This assumption appears to have been based on the fact that the manufacturers usually state that they are not stable in the presence of alkaline materials. However, the manufacturer of aldrin, dieldrin, endrin, and isodrin states that these compounds are not affected by alkaline substances ordinarily encountered.

There appears to be no experimental evidence to support the theory that organic insecticides break down or lose their effectivenesss when formulated as dust mixtures with calcium carbonate. On the contrary, considerable research has been conducted which indicates that neither occurs.

Calcium carbonate has an alkaline reaction in suspension with water because of certain impurities. The pH measurement, however, does not indicate the total alkalinity present, and it is erroneous to assume that a compound will break down or lose its effectiveness when mixed with a substance of high pH unless the total alkalinity is also high. Total alkalinity is measured from the quantity of standard acid that is required to neutralize the base.

Tyner (1947) found that a dust containing 10 per cent of DDT in finely ground lime rock had not lost its potency after it had been held in storage for a year. According to Hopkins *et al.* (1952) there is no chemical action between calcium carbonate and DDT. Roth (1948) concluded that prophyllite, calcium carbonate, and a high magnesium lime are relatively inert when combined with DDT.

In laboratory tests Rainwater & Ivy (1951) found that parathion and BHC were stable when mixed with low-lime calcium arsenates, but lost their effectiveness rapidly when mixed with high-lime calcium arsenates. Similar results in field experiments had been reported by Dunnam & Calhoun (1948), Ewing & Parencia (1948), Gaines & Young (1948), and Roussel & Gaines (1949).

Since more information was needed on the stability of insecticide dusts formulated with calcium carbonate, biological tests were conducted against certain cotton insects.

LABORATORY AND FIELD-CAGE TESTS.—*Materials and Methods.*—Calcium carbonate described as ground limestone treated with a chemical to produce a free-flowing nonwettable powder, was used in preparing these dusts. A product having a pH of 8.80 and a density of 34.37 pounds per cubic foot was used for preparing dusts containing parathion and BHC. Dusts containing the same insecticides were prepared with pyrophyllite as the diluent. This material had a pH of 6.65 at the time of mixing and is reported (Watkins & Norton 1947) to have an apparent density of 30 pounds per cubic foot. When dusts containing EPN, DDT, toxaphene, and heptachlor were prepared, the ground limestone had a pH of 9.25 and that of pyrophyllite used for comparison was 6.45.

Dust concentrates of the insecticides were ground with the diluent in a ball mill for 15 minutes, sufficient diluent being added to give finished dusts of the following strengths:

PAID PAPER.
[1] These studies were made in cooperation with the Texas and Mississippi Agricultural Experiment Stations. They were supported in part by grant-in-aid funds from the Calcium Carbonate Company, Quincy, Ill. This company also furnished the calcium carbonate used in these tests.

	Per cent
BHC, 6 per cent gamma	1
Parathion, 15 per cent	0.5
EPN, 27 per cent	3
DDT, 50 per cent	5
Heptachlor, 50 per cent	5
Toxaphene, 40 per cent	20

As soon as a dust was prepared, one-half was placed in a glass bottle, which was tightly stoppered and held in the laboratory at room temperature. The remaining portion was placed in a paper bag and held in a chamber at 100 per cent relative humidity. Freshly prepared dusts of the various toxicants diluted with pyrophyllite were used for comparison with dusts that had been held in storage. All dusts were applied at the rate of 10 pounds per acre, except the DDT dusts tested after 6 weeks in storage, when it was applied at 40 pounds per acre.

Tests with BHC and parathion.—BHC and parathion dusts were prepared on March 30, 1951, and immediately placed in storage. Standard laboratory tests aganist the cotton aphid, *Aphis gossypii* Glov., on seedling cotton plants were conducted at various intervals after the dusts had been mixed. Four replicates using a total of approximately 700 insects constituted each test. Results were evaluated on the basis of reduction in population 3 days after treatment, corrected for the population on comparable untreated plants. These results are summarized in table 1.

Table 1.—Comparative effectiveness against cotton aphids of BHC and parathion dusts formulated with calcium carbonate and pyrophyllite after being held under different storage conditions for various periods. (Rate, 10 pounds per acre.)

Insecticide	Weeks in Storage	Per Cent Reduction After Treatment with Dusts— Stored in Glass Bottles at Room Temperature	Stored in Paper Bags at 100% Relative Humidity	Fresh Mixtures
	Calcium carbonate dusts			
BHC, gamma 1%	6	53.4	51.1	—
	14	48.3	49.7	—
	36	26.0	25.1	—
	55	39.9	24.9	—
	66	29.7	24.8	—
Parathion 0.5%	6	73.7	61.6	—
	14	61.5	61.7	—
	36	40.7	28.2	—
	55	62.3	59.1	—
	66	83.4	58.0	—
	Pyrophyllite dusts			
BHC, gamma 1%	6	51.3	41.7	—
	14	32.8	63.6	39.4
	36	46.3	40.1	48.4
	55	21.1	46.3	35.5
	66	18.0	38.5	34.0
Parathion 0.5%	6	67.3	72.8	—
	14	55.7	54.8	64.6
	36	36.1	25.6	45.5
	55	66.1	68.4	76.7
	66	77.1	41.1	59.1

These data clearly show that there was no appreciable breakdown of BHC or parathion when formulated with either calcium carbonate or pyrophyllite. However, when BHC diluted with calcium carbonate was stored at 100 per cent relative humidity, it appeared to lose some of its effectiveness between the 6th and 14th weeks in storage. When held in glass bottles at room temperature, however, this dust was more effective than the dust made with pyrophyllite in all tests except the one after 36 weeks, and was as effective as freshly prepared dusts.

Neither of the parathion dusts showed any loss in effectiveness when held under either condition of storage.

Tests with EPN, toxaphene, and heptachlor.—The EPN, toxaphene, and heptachlor dusts were prepared on July 7, 1951, and placed in storage as described above. All the dusts were evaluated in standard field-cage tests against the boll weevil, *Anthonomous grandis* Boh., at various intervals after they were mixed. There were four replicates with approximately 150 boll weevils for each dust. Freshly perpared pyrophyllite dusts containing the different toxicants were also included for each dust. Results were evaluated on the basis of reduction in population 5 days after application, corrected for the population in comparable untreated check cages. The results are summarized in table 2.

There was no evidence of a significant breakdown or loss in effectiveness of EPN, toxaphene, or heptachlor when formulated as dust mixtures with calcium carbonate or pyrophyllite and held under either storage condition for 1 year.

Tests with DDT.—The DDT dusts were prepared on July 7, 1951, and placed in storage as previously described. Three tests were made at various intervals, the first two with four replicates in laboratory cages, and the final one with three replicates in field cages.

It was originally intended to test these mixtures against the bollworm, *Heliothis armigera* (Hbn.), but at the time the first two tests were scheduled a sufficient number were not available. Therefore, the cotton aphid was used in the first test and the

Table 2.—Comparative effectiveness against boll weevils of EPN, toxaphene, and heptachlor dusts formulated with calcium carbonate and pyrophyllite after being held under different storage conditions for various periods. (Rate, 10 pounds per acre.)

Insecticide	Weeks in Storage	Per Cent Reduction After Treatment with Dusts— Stored in Glass Bottles at Room Temperature	Stored in Paper Bags at 100% Relative Humidity	Fresh Mixtures
	Calcium carbonate dusts			
EPN 3%	6	87.6	78.3	—
	16	90.2	92.5	—
	52	64.5	67.3	—
Toxaphene 20%	6	84.5	68.7	—
	16	78.3	86.1	—
	52	40.9	49.8	—
Heptachlor 5%	6	62.9	57.4	—
	16	76.2	84.8	—
	52	24.1	25.7	—
	Pyrophyllite dusts			
EPN 3%	6	82.0	87.0	95.8
	16	92.0	95.6	92.8
	52	56.0	72.3	44.4
Toxaphene 20%	6	81.0	79.3	76.8
	16	72.7	80.2	76.9
	52	43.9	48.9	53.8
Heptachlor 5%	6	54.2	56.1	40.4
	16	88.6	75.2	79.1
	52	20.3	49.7	39.8

mirid *Polymerus basalis* (Reut.) in the second. Approximately 750 cotton aphids, 325 mirids, and 55 bollworms were used.

Even though DDT at ordinary dosages is not highly specific against the cotton aphid, it does have some effect. Therefore, against this species the dust was applied at the rate of 40 pounds per care, so that any breakdown in effectiveness of the dusts could be detected.

The result against cotton aphids was evaluated on the third day and against the other two species on the fifth day after application, corrected in each instance for the populations alive in comparable untreated cages at the end of the test period.

As is shown in table 3, no breakdown or loss in effectiveness was indicated when DDT was formulated with pyrophyllite or with calcium carbonate and held under either condition of storage described for a period of 1 year.

FIELD TESTS.—After it was found that this specially prepared calcium carbonate did not affect the stability of insecticides formulated with it, the practical field usage of this material as a diluent for insecticide dusts needed to be determined. Consequently, small-plot and large-scale field tests were conducted. For these tests 2 tons each of a dust containing 20 per cent of toxaphene and one containing sufficient BHC to give 3 per cent of the gamma isomer plus 5 per cent of DDT (3-5-0) were prepared in the winter of 1951 at a local insecticide-blending plant. Clays were used to prepare the base concentrates, which were than combined with approximately equal amounts of special calcium carbonate to make the finished dusts. They were stored under normal warehouse conditions until applied 6 to 7 months later.

The toxaphene and 3-5-0 dusts, when distributed in the field with ground machines and by airplane, gave a good dust cloud, and no aggregates could be detected on plant leaves. No packing or bridging of dust was observed in any of the hoppers. These dusts were much better in physical quality than most commercial dusts available on the local market.

Although the hot dry season of 1952 was very poor for evaluating insecticide formulations, each of the experimental dusts was tested in the field against boll weevils and lepidopterous larvae commonly known as bollworms. Regular commercial dusts containing 10 per cent of toxaphene plus 1.5 per cent of parathion, and 2 per cent of methyl parathion plus 5 per cent of DDT were used in the small plots. In the large-scale field tests commercial dusts containing 20 per cent of toxaphene, and 3-5-0 were used for comparison. The dusts were applied with ground machines on 1/4-acre plots, which were replicated three times. All the plots were treated three times at approximately 10 pounds per acre.

The early boll weevil infestation was

Table 3.—Comparative effectiveness against cotton insects of DDT dusts formulated with calcium carbonate and pyrophyllite after being held under different storage conditions for various periods.

Insect	Weeks in Storage	Pounds of Dust per Acre	Per Cent Reduction After Treatment with Dusts— Stored in Glass Bottles at Room Temperature	Stored in Paper Bags at 100% Relative Humidity	Freshly Prepared
		Pyrophyllite dust			
Cotton aphids	6	40	36.8	35.5	38.2
Polymerus basalis	16	10	71.7	79.1	72.4
Bollworms	52	10	53.1	46.3	52.5
		Calcium carbonate dust			
Cotton aphids	6	40	30.3	37.0	—
Polymerus basalis	16	10	69.8	81.5	—
Bollworms	52	10	55.4	64.4	—

very light in all plots, and it remained so throughout the season, averaging less than 1 per cent. The bollworm square infestation in the plots treated with the experimental dusts ranged from 7 to 10 per cent, with a seasonal average of 5 per cent, compared with 8 to 13 per cent, with a seasonal average of 5 per cent after the use of commercial dusts. The average gains in seed cotton per acre, after the use of the two types of dusts were 241 and 338 pounds, respectively.

Insecticide applications by airplane were made on four fields varying in size from, 6 to 16 acres. All the fields were treated four times. Before the experimental dusts were applied, the boll weevil infestation averaged 60 per cent in two fields, but it was reduced to 25 and 28 per cent 14 days after treatment, when dusting was discontinued. In the other two fields the average infestations were 12 and 13 per cent before the commercial dusts were applied. When the dusting was discontinued at the end of 14 days, the boll weevil infestation had been reduced to 3 and 10 per cent.

The seasonal bollworm-square infestation was very light, averaging 1.4 per cent after the use of both types of dusts. No check field was available. The average yield was 1,040 pounds per acre with the experimental dusts and 1,290 pounds with the commercial dusts. These differences in yield should not be attributed to differences in boll wevil control, because of the great variations in infestation when the tests were started and because dry weather caused much shedding at the conclusion of the treatments.

SUMMARY AND CONCLUSIONS.—Biological tests were conducted to determine the stability of insecticide dusts formulated with calcium carbonate as the diluent.

BHC and parathion dusts were tested against the cotton aphid, *Aphis gossypii* Glov., EPN, toxaphene, and heptachlor dusts against the boll weevil, *Anthonomus grandis* Boh., and DDT dusts against the cotton aphid, the mirid, *Polymerus basalis* (Reut.), and the bollworm, *Heliothis armigera* (Hbn.).

The calcium carbonate used was ground limestone that had been treated with a chemical reagent to produce a free-flowing ing, nonwettable powder. The dusts were held in storage in glass bottles at room temperature or in paper bags at 100 per cent relative humidity, and tested at intervals for a year or more. Dusts of the same insecticides formulated with pyrophyllite were tested for comparison.

The only evidence of breakdown or loss in effectiveness occurred sometime between 6 and 14 weeks after the BHC-calcium carbonate dust had been held in paper bags at 100 per cent relative humidity. After a slight loss, however, the mixture apparently remained stable during the rest of the 66 weeks in storage.

These tests indicate that the insecticides will remain stable when formulated in dusts with a free-flowing, nonwettable form of calcium carbonate and held under ordinary dry storage conditions for a year or more.

In dusting quality formulations prepared with the special calcium carbonate were greatly improved over regular commercial dusts when applied by ground machines and airplane.

In field tests dusts containing 20 per cent of toxaphene, and sufficient BHC to give 3 per cent of the gamma isomer plus 5 per cent of DDT formulated with this special calcium carbonate, gave just as good control of the boll weevil and the bollworm as the same toxicants, and others, prepared with commercial diluents.

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Microbioassay of Insecticides in Milk by a Feeding Method

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When cows are fed or treated with an insecticide, the toxicant can soon be found in their milk. From the standpoint of safety in human consumption it is important to be able to analyze minute quantities of the toxicant in milk. The analysis of a toxicant by extracting it from milk is a long, tedious process, and the accuracy of either bioassay or chemical analyses of such extracts may be greatly affected by possible losses during each step of handling or by the presence of interfering substances extracted from milk.

Attempts have been made to test the toxicity of DDT in milk or cream by feeding it to house flies (Carter *et al.* 1949 and Wingo & Crisler 1948). However, owing to its low toxicity to house flies no definite method has been suggested for the determination of DDT in milk or cream. DDT concentrations of 50 p.p.m. or less could not be definitely detected on the basis of fly mortality. (Carter *et al.* 1949).

The purpose of this paper is to report a method of analyzing microquantities of dieldrin in cow's milk by feeding the house fly, *Musca domestica* L., with treated milk and to illustrate the application of the method to determine microquantities of other insecticides in milk or possibly other liquid food. The sensitivity of the feeding method depends largely upon the toxicity of an insecticide in milk to the test insect. The principles and precautions described by Sun & Sun (1952) can also be applied here with equal importance.

PREPARATION OF MILK SAMPLES.—The success of the feeding method depends upon the uniform distribution of a toxicant in milk. On standing the emulsion of milk will gradually break down. If a milk sample cannot be remixed into a homogeneous emulsion it cannot be tested by the feeding method. The following methods of obtaining and preserving milk samples are recommended, especially when samples cannot be tested immediately after milking.

Before treating animals with an insecticide, a sufficient quantity of milk should be taken for use in making standards or for diluting treated milk samples. The amount of untreated milk required for one series of experiments is two to three times as much as a treated milk sample times the number of series of tests. An adequate volume of a treated milk sample required for the feeding method is 250 ml.

To each 250 ml. of untreated or treated milk samples, 0.5 ml. of 40 per cent formaldehyde (c.p. grade) is added as a preservative. Then each sample is uniformly mixed by vigorous shaking, homogenized with a hand homogenizer,[3] and stored in a refrigerator at about 5° C. After storage, each sample should be thoroughly shaken and again passed through a hand homogenizer just before testing. Samples which had been kept at 5° C. for six weeks and retested did not give any noticeable change in the appearance of the emulsion or the results of analysis. The homogenizer should be thoroughly washed with a detergent, tap water and then distilled water after its use for processing each sample.

FEEDING METHOD.—The feeding method has been used in the determination of dieldrin in milk obtained from several series of experiments. Standards containing various amounts of dieldrin (expressed in parts per million or p.p.m.) are prepared, as illustrated in table 1, by

PAID PAPER.
[1] Resigned.
[2] The authors wish to acknowledge the assistance of E. R. Johnson in some tests.
[3] Homogenizer, hand model; capacity of bowl 12 ounces; approximate pressure at orifice 600 lbs.; obtainable at Arthur H. Thomas Co., or other companies supplying laboratory equipment.

Table 1.—Preparation of standard milk samples and results of evaluation of a treated milk sample.

Milk Sample	Methods of Preparing Standards for Tests	Dieldrin in Milk, P.P.M.	Average Per Cent Mortality 44 Hours	Dieldrin Found in Treated Milk, P.P.M.
Standard (made from untreated milk)	0.6 ml. 0.1% dieldrin plus 99.4 ml. untreated milk	6	—	
	40 ml. milk (6 p.p.m.) plus 40 ml. untreated milk[1]	3	84	
	30 ml. milk (6 p.p.m.) plus 60 ml. untreated milk[1]	2	60	
	30 ml. milk (3 p.p.m.) plus 30 ml. untreated milk[1]	1.5	29	
	30 ml. milk (2 p.p.m.) plus 30 ml. untreated milk[1]	1	3	
Treated milk		Unknown[2]	31	1.5
		Unknown[2] (duplicate)	27	1.45

[1] 2 replicates.
[2] 3 replicates.

adding a calculated volume of 0.1 per cent dieldrin-acetone solution to untreated milk to form a "colloidal solution." After thoroughly shaking, it is further diluted with untreated milk to suitable concentrations which will be used to feed flies. To insure a uniform distribution of the toxicant in milk it is important to thoroughly shake milk samples before each measurement and after each dilution. It was found that such small amounts of acetone did not have any apparent toxic effect upon house flies. However, it is advisable to use comparable amounts of acetone in treated samples in order to compensate for any possible effect of acetone. The change of volume by adding dieldrin solution to untreated milk is only 0.1 and 0.6 per cent for standards containing 1 and 6 p.p.m. of dieldrin respectively. This slight difference in volume does not appreciably affect the results, even without adjustment or correction. In order to reduce the amount of acetone in the standards, a 1 per cent dieldrin-acetone solution may be first added to water to form a 0.1 per cent colloidal solution. Then various required volumes of the colloidal solution of dieldrin are measured and added to untreated milk to obtain suitable standards.

Both standards and treated samples are prepared for test by measuring into a wide-mouth pint jar 20 ml. of milk which is absorbed on 1.2 grams of cotton. One hundred 1-day old house flies anesthetized with carbon dioxide are counted into each jar which is then covered with a piece of cheese cloth and kept at 27° C. for further observation. Two replicates are used for each of four concentrations of standards. For treated milk samples containing lower concentrations of dieldrin, six replicates are used instead of three. The whole series of experiments should be repeated another day. The average of the above two values is used as the final result. The time of observing mortality varies from 17 to 48 hours depending upon the mortality of flies. Since both samples and standards are counted at the same interval of time and since dieldrin is present in both standards and samples, there are no appreciable differences in results by actual tests when the mortality is counted at 17-hour to 48-hour intervals. By testing the same sample twice, it was found that the toxicant was 2.6 and 2.8 p.p.m. when the mortality was counted at 28 and 46 hours respectively. If the insecticide content in milk is very high, the sample can be diluted with untreated milk in order to get a proper range of mortality. Generally, the mortality counts are taken when the mortality of flies in jars containing treated milk samples falls into a proper range of comparison, usually between 20 and 80 per cent. The average mortality of flies in control tests with untreated milk was 0.12 per cent (17 tests) within 24 hours, and 3.4 per cent (12 tests) at the end of 48 hours. High mortality in the control may mean contamination by insecticides or other trouble and the experiment should be repeated. In table 1, an interpolation method was used for the

evaluation of results. The average mortality of flies fed with treated milk samples is superimposed on the standard dosage-mortality curve made on the same day and plotted on log-probit scales. The amount of dieldrin in a treated milk sample is read directly from the curve in p.p.m.; in a specific case 1.5 and 1.45 p.p.m. were found in duplicate tests. Other methods described by Sun and Sun (1952) for analyzing insecticide residues can also be applied to the feeding method according to the amount of a toxicant in the sample. If the amount of dieldrin in the treated milk samples is too low to kill house flies the same amounts of dieldrin can be added to both samples and standards. By subtracting the added amount of dieldrin from the results, dieldrin in milk can be determined as low as 0.1 to 0.2 p.p.m. Statistical analysis should be used to establish the presence or absence of such small quantities of insecticides.

RESULTS AND CONCLUSION.—An example is shown in table 1, in which the method of preparing standards and evaluating results for a treated sample are given. The validity of adding a small amount of the same toxicant to sublethal concentrations of dieldrin in milk was illustrated by Sun and Sun (1952). The average variation of results of four determinations is only 0.15 p.p.m. for a milk sample containing 1.5 p.p.m. of dieldrin. This variation is within the limit of experimental variation. The sensitivity for the feeding method can be calculated by the following equation.

$$\text{Sensitivity of feeding method} = D \times F$$

Where D is the LD 50 of a standard expressed as p.p.m. of a toxicant in milk and F is a factor of accuracy which may vary from 0.2 to 0.1, depending upon the number of replications and the accuracy of results. The equation is a modification of the one suggested for testing the sensitivity of the residue method by exposing flies to a "dry" film of deposit (Sun and Sun, 1952). Since the feeding method gives more consistent results than the residue method, 0.1 is used for F in the calculation of sensitivity.

Table 2.—Microbioassay of recovery samples by feeding house flies.

Sample No.	Dieldrin Added to Milk, P.P.M.	Dieldrin Found, P.P.M.
1[1]	0.1	0.13
2[1]	0.1	0.16
3	0.1	0.05
4	0.1	0.12
5	0.3	0.32
6	0.3	0.26

[1] Submitted by cooperators.

Table 3.—Sensitivity of microbioassay of several toxicants in milk by feeding method, based on four determinations.

Toxicants	Average LD 50 (48-Hour Count) P.P.M.	Calculated Sensitivity, P.P.M.	
		By Direct Comparison (0.7 of LD 50)	By Adding Toxicant to Samples (0.1 of LD 50)
Dieldrin[1]	0.96	0.67	0.10
Aldrin[2]	1.13	0.79	0.11
Lindane[3]	1.77	1.2	0.18
Isodrin[4]	5.39	3.8	0.54
Endrin[5]	5.72	4.0	0.57
DDT[6]	13.6	9.5	1.4

[1] m.p. 175–176° C., Julius Hyman & Co.
[2] m.p. 103–104° C., Julius Hyman & Co.
[3] m.p. about 110° C.
[4] Recrystallized, Julius Hyman & Co.
[5] Recrystallized, Julius Hyman & Co.
[6] Setting point, 150° C.; not less than 98% pp'-DDT; Geigy Co., Inc.

The average LD 50 of dieldrin in milk is about 2 p.p.m. when tested by the feeding method with 1-day-old house flies; therefore, the sensitivity is 2×0.1, or 0.2 p.p.m. of dieldrin.

When a higher sensitivity, such as 0.1 p.p.m. of dieldrin, is required, house fly pupae, from which flies are ready to emerge, should be transferred into an empty cage without food at the end of a working day. Early the next morning newly-emerged flies, less than 17 hours old, are ready for tests. These younger and hungry flies are more susceptible to the toxicant in milk. The average LD 50 for dieldrin is 0.96 p.p.m. (Table 3), and a sensitivity of 0.1 p.p.m. can be obtained.

Recovery samples (Table 2) have been analyzed by this method. Samples 1 and 2 were sent as "unknowns" by cooperators, 0.1 p.p.m. of dieldrin was added to samples 3 and 4, and 0.3 p.p.m. to samples 5 and 6 before the tests. The result of each recovery sample is an average of two determinations. The average recovery of 4 samples at 0.1 p.p.m. is 0.115 p.p.m. or 115 per cent, and the average recovery of 2 samples at 0.3 p.p.m. is 0.29 p.p.m. or 97 per cent. On the basis of a number of

determinations, an apparent amount of 0.06 p.p.m. (or more) of dieldrin in milk, tested by the above feeding method, gives a significant difference in mortality (about 10 per cent) at the 0.05 level when analyzed by the ranking method (Wilcoxon 1946).

This feeding method can be used for the microbioassay of other toxicants in milk obtained from other animals or in liquid food which can be fed to house flies or other insects. Experiments have been made in testing the toxicity to house flies (not more than 17 hours old) of dieldrin, aldrin, lindane, isodrin, endrin and DDT in milk. The average LD 50 values obtained at 48-hour intervals are 0.96, 1.13, 1.77, 5.39, 5.72 and 13.6 p.p.m. of toxicant for dieldrin, aldrin, lindane, isodrin, endrin and DDT, respectively (Table 3). From LD 50 values, the approximate sensitivity of each toxicant has been calculated on the basis of direct comparison (0.7 of LD 50), as well as by adding the toxicant to samples (0.1 of LD 50). The factors used in the calculation are based on a significant difference in mortality. On the basis of results in table 3, the sensitivity which can be obtained for detecting the above toxicants in milk is 0.10 p.p.m. of dieldrin, 0.11 p.p.m. of aldrin, 0.18 p.p.m. of lindane, 0.54 p.p.m. of isodrin, 0.57 p.p.m. of endrin and 1.4 p.p.m. of DDT. The sensitivity of detecting these toxicants can further be improved by using younger flies, male flies, smaller flies, or longer intervals of observing mortality.

SUMMARY.—A microbioassay method has been devised to determine dieldrin in milk by direct feeding of house flies with homogenized milk. The results are obtained in parts per million of toxicants by comparing the mortality of flies in treated samples against the mortality in standards which are prepared by adding known amounts of the same toxicant to an untreated check. This method can detect as low as 0.1 p.p.m. of dieldrin or aldrin, 0.2 p.p.m. of lindane, 0.5 to 0.6 p.p.m. of isodrin or endrin and 1.4 p.p.m. of DDT in milk.

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Reduced Spray Programs for Citrus for Canning Plants in Florida[1]

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Each succeeding year finds a larger proportion of Florida citrus fruits being marketed as canned products. This fact suggests that external quality is of little consequence where fruit is produced for cannery use and that spray programs, primarily designed for the production of fresh fruit, may be altered at a considerable saving to the grower. In 1947, it was found that for 8 years two plots of grapefruit at the Citrus Experiment Station had produced more fruit per tree per year than did other trees within the same block which had received normal spray programs. Therefore, an experiment to determine if fruit could be satisfactorily produced for canning on a program of reduced spray and dust applications was inaugurated. This paper presents a 4-year comparison of such spray programs.

One spray program was complete and similar to that which is practiced in most groves in Florida. This consisted of a spray in January or February of zinc, DN,[3] and wettable sulfur; a post-bloom spray of copper and wettable sulfur; a summer oil

[1] Florida Agricultural Experiment Station Journal Series, No. 86. Presented at the annual meeting of the American Association of Economic Entomologists at Cincinnati, Ohio, December 10–13, 1951.

[2] Resigned in 1951.

[3] A commercial preparation containing 40% Dinitro-o-cyclohexylphenol.

Table 1.—Effect of three pest control programs on external quality of fruit. Percentage of fruit in either first or third grade.

	SEEDY GRAPEFRUIT						VALENCIA ORANGES					
	Complete		Dust		No Treatment		Complete		Dust		No Treatment	
YEAR	1st	3rd	1st	3rd	1st	3rd	1st	3rd	1st	3rd	1st	3rd
1948	37	14	28	20	11	34	66	4	70	3	66	3
1949	22	30	1	50	5	68	24	31	7	43	1	17
1950	48	5	57	7	28	32	—	—	—	—	—	—
1951[1]	29	33	14	42	18	48	—	—	—	—	—	—
Avg.	34.0	20.5	25.0	29.8	15.5	45.5	45.0	17.5	38.5	23.0	33.5	10.0

[1] Includes only 4 of 6 replicates.

emulsion spray for control of Florida red scale, *Chrysomphalus aonidum* (L.), and purple scale, *Lepidosaphes beckii* (Newm.), and sulfur as needed for control of the citrus rust mite, *Phyllocoptruta oleivora* (Ashm.), during the fall and winter months. The second program consisted of sulfur dust only. This was applied so as to protect the fruit from injury by citrus rust mite, *Phyllocoptruta oleivora* (Ashm.), and no effort was made to prevent the formation of "greasy spot"[4] rust mite injury on the foliage. The third program was an unsprayed control. Both of the latter two sets of plots were to be sprayed if serious injury appeared imminent from scale or from citrus red mite, *Paratetranychus citri* (McG.). This contingency did not arise during the course of the years, 1948, 1949, and 1950, but in 1951 two of the sulfur dust plots required scale control.

Each plot contained at least 25 trees and all treatments were replicated six times—four times in one grove and twice in a second one. Most of the trees were large seedy grapefruit. In addition, in some of the plots sufficient Valencia orange trees were present to allow observations on oranges as well as grapefruit. As much material as would normally have been applied by commercial operators, or more, was dusted or sprayed on these trees. During the 4-year interval, 1948–1951, five plots were mistakenly sprayed with oil. In 1948 two dust and two unsprayed control plots and in 1950 an unsprayed control plot were sprayed.

Yield records were recorded for each tree and a standard field box, 90 pounds, was used as the unit of measure. Grapefruit from each of four trees in each plot was graded in the packinghouse at the Citrus Experiment Station. Records[5] of injury, size, and grade were recorded by trees, and plot averages were obtained. During the first 3 years samples were also taken from each plot for tests of internal quality. Wherever possible Valencia oranges were also checked in the packinghouse.

RESULTS AND DISCUSSION.—Costs were compared by using dealer insecticide prices and charging the expense of spraying at 0.75 cent per gallon and dusting at 1.5 cents per pound. Thus, it was found that the cost of the complete spray program would have varied between $1.00 and $1.30 per tree per year during the course of the experimental period. The dust program averaged about 15 cents per tree, and where no sprays or dusts were applied there was no charge for pest control. This meant that spray costs on the complete spray program varied from 8 to 20 cents and dust costs from 1.5 to 4 cents per box of grapefruit. These figures are comparable to those obtained in commercial grove operations.

Table 1 shows the effect of spray program upon grade of both grapefruit and Valencia oranges, but only the per cents of fruit found in first and third grades are shown. Grading was severe and the fruit in first grade was of better quality than would be found in most commercial packinghouses. The complete spray program produced the highest percentage of first grade grapefruit, and the dust program produced an intermediate amount, while the lowest number of first grade and the most third grade fruit was produced

[4] Injury to leaves that sometimes develops following a citrus rust mite infestation.

[5] Complete records for the 1951 season were not obtained, but those taken are included in the tables presented.

Table 2.—Effect of three pest control programs on external quality of fruit. Percentage of fruit with enough melanose infection to reduce quality to second or third grade.

	Seedy Grapefruit						Valencia Oranges					
	Complete		Dust		No Treatment		Complete		Dust		No Treatment	
Year	2nd	3rd	2nd	3rd	2nd	3rd	2nd	3rd	2nd	3rd	2nd	3rd
1948	19[1]		62[1]		81[1]		5	0	26	1	38	3
1949	67	19	62	33	70	27	58	12	62	9	65	3
1950	13	2	6	2	10	2	3	1	3	0	2	0
1951[2]	49	18	51	34	49	36	—	—	—	—	—	—
Avg.	37	13	45	23	53	20	22	4	30	3	35	2

[1] Second and third grade not differentiated.
[2] Includes only 4 of 6 replicates.

on the unsprayed check plots. In the case of the Valencia oranges in 1948 it was found that the number of fruit in first grade on the complete program was reduced because of green color. This was apparently due to the fact that oil sprays applied in the preceding July adversely affected the color of Valencias picked the following May. Similar data has been reported previously for other varieties (Sites & Thompson 1948). In 1949 much of the fruit was coarse, due to off-bloom after a dry spring. As a result, grade was poor in all plots.

Table 2 shows the percentage of fruit placed in either second or third grade due to the presence of melanose. Melanose, a fungus infection which causes an unsightly blemish on the outside of the fruit, is controlled by the use of copper at post-bloom time. According to personal correspondence with technical men employed in commercial canneries, melanose is not detrimental when fruit is to be juiced. The use of copper materially reduced the amount of grade-out due to melanose in seedy grapefruit. In the case of oranges there was less difference due to the use of copper. This is typical of commercial groves, where it has been found that melanose is less severe on oranges than on grapefruit.

Table 3 shows the percentage of fruit with citrus rust mite injury. These differences are attributable to differences in the regularity of sulfur applications. Sulfur was applied according to the percentage of grapefruit infested with citrus rust mites and, since oranges tend to be injured more readily, a higher percentage of fruit was marked in the case of the Valencia oranges than in the case of the seedy grapefruit. Citrus rust mite population averages for the 4-year period under discussion are shown in table 4. It will be noted that far more citrus rust mites were present in the unsprayed controls than in the two treated plots.

Regular counts of citrus red mites were not made during the first 2 years. In none

Table 3.—Effect of three pest citrus control programs on external fruit quality. Per cent of fruit with early or late citrus rust mite injury.

	Seedy Grapefruit						Valencia Oranges					
	Complete		Dust		No Treatment		Complete		Dust		No Treatment	
Year	Early	Late	Early	Late	Early	Late	Early	Late	Early	Late	Early	Late
1948	0	2	0	3	2	6	3	0	8	1	17	2
1949	1	5	5	11	9	54	18[1]	5	21[1]	30	20[1]	78
1950	4	3	4	2	34	6	38	3	58	1	84	9
1951[2]	1	19	2	17	10	30	—	—	—	—	—	—
Avg.	1.5	7.3	2.8	8.3	13.8	24.0	19.3	2.7	29.0	10.7	40.3	29.7

[1] Mostly blossom-end russeting.
[2] Includes only 4 of 6 replicates.

Table 4.—Comparison of three pest control programs with respect to average rust mite and citrus red mite infestations.[1]

YEAR	CITRUS RUST MITES			CITRUS RED MITES		
	Complete	Dust	No Treatment	Complete	Dust	No Treatment
1948	5	17	27	—	—	—
1949	9	14	49	—	—	—
1950	13	28	63	23	91	3
1951	4	11	31	11	25	7

[1] Citrus red mite counts made on foliage. Citrus rust mite counts were made on foliage if fruit was not present.

of the 3 years were these mites severe enough to cause injury in any of the plots. However, in 1950 and 1951, when monthly counts were made throughout the year, it was found that the highest average citrus red mite infestation was on the sulfur dust plots. The lowest infestation was on the unsprayed check, and the citrus red mite population was intermediate on the complete spray program. This is in agreement with data reported by Grifiths & Thompson (1950) where it was shown that sulfur seemed to be a major factor in the build-up of citrus red mite populations on citrus in Florida.

Table 5 shows the percentage of fruit with either purple scale or Florida red scale on the peel. Only on the complete spray program was a spray regularly applied for the control of scale insects. As previously noted, mistakes were made in 1948 and in 1949, when five plots were sprayed with oil accidentally. In 1951, two sulfur dust replicates were sprayed with oil, but fruit from these plots was not checked in the packinghouse. However, the majority of the plots both on the dust and on the non-treatment program received no oil sprays throughout the 4-year period. It will be noted that the most purple scales on both grapefruit and oranges were found on fruit from the sulfur dust program, and that the least purple scales were on fruit from the unsprayed control. On both varieties the least Florida red scales were on fruit from the unsprayed control. This is in agreement with experimental data from a number of other sources (Fisher & Griffiths 1950; Griffiths & Fisher 1950). Thus, when no sprays or dusts are applied, purple and Florida red scales are not usually a major problem. They may be present in considerable abundance during the early summer, but by fall the population has been materially reduced by natural causes. Actual counts of red and purple scales were made in these plots on four occasions. In each instance the unsprayed controls had lower average Florida red scale infestations than did either of the other two series of plots, and in three of the four counts the unsprayed plots had the least purple scale. In general, the sulfur dust plots had more scales than did the completely sprayed plots. These counts further substantiated the trends noted in table 5.

"Greasy spot" on the foliage is an important problem which has never been fully evaluated. It is probably caused by citrus rust mite injury (Thompson 1948), although its formation may be complicated by other undetermined factors. It causes the leaves to drop prematurely and, although the fruit may be free from citrus rust mite injury, "greasy spot" may be common. Under these circumstances, it is believed that citrus rust mites were present on leaves without injury occurring to the fruit. In these experiments "greasy spot" was severe on the unsprayed con-

Table 5.—Comparison of three pest control programs with respect to per cent of fruit with either Florida red or purple scale on the peel.

YEAR	SEEDY GRAPEFRUIT						VALENCIA ORANGES					
	Complete		Dust		No Treatment		Complete		Dust		No Treatment	
	Red	Purple	Red	Purple	Red	Purple	Red	Purple	Red	Purple	Red	Purple
1948	3	14	3	17	1	8	2	8	3	10	1	6
1949	9	19	4	15	2	10	1	21	1	15	0	6
1950	17	10	33	20	15	11	23	9	10	16	3	4
1951[1]	22	7	15	24	4	8	—	—	—	—	—	—
Avg.	12.8	12.5	13.8	19.0	5.5	9.3	8.7	12.7	4.7	13.7	1.3	5.3

[1] Includes only 4 of 6 replicates.

trols, and it was almost as common on the dusted plots. As noted above, the dusted plots received only enough sulfur to prevent fruit injury and there was adequate opportunity for leaf injury under these circumstances. Very little "greasy spot" was noted in the complete spray plots.

Prior to the spring growth in 1950 there was severe defoliation of both unsprayed control plots and dust plots, due to the premature drop of leaves which were affected by "greasy spot." This did not occur on the complete spray program. However, regardless of this defoliation, the trees grew, bloomed, and produced a satisfactory crop during the 1950–51 season. In the spring of 1951 defoliation again occurred in the unsprayed control and the dust plots. It began in early February and continued throughout that month. In the initial stages, "greasy spot" was common on the dropped leaves. By March, trees on the complete spray program began dropping leaves, although "greasy spot" was uncommon in those plots. At that time, following the defoliation, the number of leaves on the ground appeared to be comparable in all plots; however, trees in the unsprayed control and the dust plots had thinner foliage than the trees on the complete spray program. The very severe defoliation which occurred in 1951 was similar to that which occurred in most grapefruit groves throughout central Florida. It occurred at the same time that spring growth began in the spring, and was possibly caused by the extreme number of cold days experienced during the preceding winter. In 1951, it was apparent that "greasy spot" caused the early leaf drop in the dust and untreated control plots, but most of these leaves would have dropped subsequently, as observed in the completely sprayed plots. It seems possible that the severe defoliation that occurred on the unsprayed control should be a factor in the quantity of fruit produced. Although this premise seems to be a reasonable one, there are no data presented in this paper to substantiate such a claim.

Table 6 presents a summary of yields on the three spray programs. It will be noted that yields of seedy grapefruit were very low in 1949. This was due to the fact that a hurricane reduced the grapefruit crop by approximately 60 per cent. This resulted in a lower average yield for the 4 years than otherwise would have been the case. Yield of Valencia oranges was very little, if at all, affected by the hurricane. It will be noted that on the basis of actual boxes of grapefruit produced, the complete spray program produced more fruit than did the dust or no-treatment programs. However, because of the fact that the grapefruit trees were not uniform, it was necessary to compare the yields on a weighted basis. Previous average yields of the blocks were known, and the initial plot yields taken in 1948 were considered to represent a given per cent of normal. With this as a base, an expected average yield could be determined for the three sets of experimental plots. This figure is presented in table 6. It will be noted that when the per cent of expected yield is considered there was no significant difference in amount of fruit produced by any of the three programs. This is in agreement with data from small plots of grapefruit at the Citrus Experiment Station over more than a decade. Also, there was no difference in yield of Valencia oranges between the three spray programs. On the basis of these data, it is concluded that there was no reduction in yield in these plots due to the elimination of sprays and dusts for either Valencia oranges or seedy grapefruit.

Table 6.—Comparison of three pest control programs with respect to yield of fruit in boxes per tree.

Year	Seedy Grapefruit			Valencia Oranges		
	Complete	Dust	No Treatment	Complete	Dust	No Treatment
1948	9.7	7.9	7.8	3.7	3.6	3.5
1949	4.4	4.5	3.9	1.8	3.0	2.9
1950	13.0	11.2	10.4	3.3	2.8	2.2
1951	13.0	11.9	12.6	—	—	—
Av.	10.0	8.9	8.7	2.9	3.1	2.9
Expected Av.	13.4	11.1	10.8			
Per cent of Expected Av.	74	80	81			

Tables 7 and 8 present data on internal fruit quality.[6] These figures are not based on the number of tests which would normally be desirable, but they are the best figures which time and labor permitted. Oil sprays have been reported

[6] Analyses were made under the direction of Dr. J. W. Sites of the Citrus Experiment Station.

Table 7.—Effect of three pest control programs on internal fruit quality of seedy grapefruit, size 70 sampled in packinghouse.

Year	Complete				Dust				No Treatment			
	Per Cent			Vit. C mg./100 cc.	Per Cent			Vit. C mg./100 cc.	Per Cent			Vit. C mg./100 cc.
	Soluble Solids	Acid	Ratio		Soluble Solids	Acid	Ratio		Soluble Solids	Acid	Ratio	
1948	10.13	1.30	8.07	35	10.08	1.24	8.24	35	10.18	1.21	8.30	35
1949	9.91	1.46	6.79	36	10.33	1.49	6.91	38	10.21	1.49	6.85	37
1950	9.67	1.43	6.77	35	10.08	1.53	6.63	36	10.08	1.52	6.65	36
Av.	9.90	1.40	7.21	35.3	10.16	1.42	7.26	36.3	10.16	1.41	7.27	36.0

previously (Thompson & Sites 1945) to be detrimental in the production of soluble solids. Therefore, as would be expected, fruit from both the dust and the untreated controls had higher soluble solids over the three-year period, 1948–1950, than fruit from the complete spray program. The per cent acid was not materially affected, but the ratio of soluble solids to acid was slightly higher in the case of the unsprayed controls. Since a high percentage of fruit is being used for frozen concentrate, the amount of sugar (soluble solids) produced per fruit is important. Significant difference in this latter figure were not found between the spray treatments. On the basis of these data, it would appear that fruit can be produced on unsprayed trees which has as good internal quality as that produced where a complete spray program has been in force. If parathion had been used as the scalecide in place of oil it is possible that these differences would not have been found, because parathion does not adversely affect the soluble solids in the fruit.

During the course of 3 years of these tests several unexplained phenomena occurred. In the spring of 1951 dead twigs appeared on a number of trees. These were characterized by the leaves dying quickly. The dead leaves remained in place, and only small wood was affected. Counts were made in the various plots and it was found that there were significantly more of these dead twigs on trees in the complete spray plots. This was not directly due to spray or citrus red mite injury, and no reason for the phenomenon can be offered at present.

Similarly, in the spring of 1951, a condition known as "yellow spot" (recently reported by Stewart & Leonard, 1951, to be molybdenum deficiency) was noted in these spray plots. Actual counts were again made, and there was more "yellow spot" showing in the complete spray plots than in either the dust or the unsprayed controls. There was very little difference between the dust plots and the unsprayed controls in this particular instance. The pH of the soil was determined and there was a correlation between pH and the extent of "yellow spot." It would appear that the pH of the soil had been lowered by the regular use of sulfur sprays and that "yellow spot" had resulted.

In the spring of 1949 severe drought conditions existed, and the Valencia oranges were not picked until late in the spring. A condition occurred which was characterized by the drying and discoloration of the peel of the oranges at the stylar end. Internal quality did not seem to be impaired, but the outside rind showed a dried and hardened brownish condition, which sometimes covered as much as half the orange. This breakdown was found only in the plots which did not receive oil sprays. Similar conditions were reported from commercial groves in that year. There was none of this breakdown

Table 8.—Effect of three pest control programs on internal fruit quality of Valencia oranges, size 176, sampled in packinghouse.

Year	Complete				Dust				No Treatment			
	Per Cent			Vit. C mg./100 cc.	Per Cent			Vit. C mg./100 cc.	Per Cent			Vit. C mg./100 cc.
	Soluble Solids	Acid	Ratio		Soluble Solids	Acid	Ratio		Soluble Solids	Acid	Ratio	
1948	11.75	0.85	13.79	39	12.26	0.83	14.92	38	12.48	0.73	17.25	38
1949	11.68	0.79	14.75	36	12.29	0.84	14.70	36	12.28	0.84	14.75	37
1950	11.22	0.68	16.65	31	11.40	0.73	15.70	33	11.60	0.72	16.20	36
Av.	11.55	0.77	15.06	35.3	12.32	0.80	15.11	35.7	12.12	0.76	16.07	37.0

in the plots that received complete spray program, in spite of the fact that one of these suffered more severely from drought than did the unsprayed plots. The full significance of this was not determined.

The data presented here show that where no sprays or dusts are applied, the following conditions will likely occur: yields may not be adversely affected; citrus rust mite injury will be increased; melanose injury to fruit will be increased, especially on grapefruit; scale insects and citrus red mites may not be a major problem; and internal quality will be as good as, if not better than, on trees receiving a complete spray program. In these experiments these results have been true over a 4-year period. It is too early to recommend this type of program to growers on a large scale, for such a program may have many pitfalls which have not been determined in this relatively brief experimental period. It is believed, however, that these data indicate that there can be material reduction in the amount of spraying and dusting. Furthermore, it is believed that this will not affect internal quality, so that the fruit will be satisfactory for canning plant usage. This information is applicable only to those groves where it is decided at the beginning of the year that the fruit will be raised expressly for canning plant purposes. Adherence to such a program will, in many years, render the fruit so unsightly that it cannot be shipped in fresh fruit channels.

SUMMARY AND CONCLUSIONS.—Over a 4-year period unsprayed trees were compared with trees treated only with dusting sulfur for citrus rust mite control and with plots that received a complete spray program. These plots were compared on the basis of number of scale insects, amount of citrus rust mite injury, amount of melanose injury, internal fruit quality, and average yields. Although external quality varied considerably and was inferior on the unsprayed controls, yield and internal quality were as good as on the complete spray program. It is concluded that there are definite possibilities in Florida for reducing the total number of sprays and dusts on citrus, where fruit is to be produced for canning plant purposes.

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The Role of Chlorinated Polyphenyls in Improving Lindane Residues[1]

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The use of lindane and other volatile insecticides to leave toxic residues on surfaces presents several problems. With lindane deposits the following problems may be encountered:

(1) The appearance of a crystalline deposit may be objectionable.
(2) It evaporates so rapidly that repeated treatments may be necessary.
(3) The crystals may be removed by mechanical contact.
(4) Weathering may remove the toxicant in outdoor applications.
(5) On very porous surfaces there may be a rapid loss of toxicity through sorption of the insecticide.
(6) The cost of lindane is high.

A film-forming material in which the insecticide is soluble will prevent crystallization, reduce the volatilization rate, and if the proper material is chosen, provide a tight bond to the surface being treated. The problem of cutting down sorption on porous surfaces is essentially one of finding appropriate methods of application.

Prolonged insecticidal effectiveness has been obtained by incorporating the toxicant in a nonvolatile oil. However, on porous surfaces this oil solution penetrates rapidly and toxicity is soon lost, and on nonporous surfaces a wet oily film is left which may be very undesirable.

Lindquist *et al.* (1945), Campbell & West (1944a, b), and others have suggested the incorporation of DDT in paints. Block (1948) has made a comprehensive survey of the field of insecticide coatings. In general, oil films, oil-modified resins, or rosin derivatives produced coatings with DDT having poor insecticidal quality. Among paint vehicles from natural products an asphalt varnish derived from gilsonite appeared to be satisfactory. Water-dispersible vehicles, such as casein and glue, were found not to be so toxic as expected. Various synthetic resins including urea-formaldehyde appeared promising.

In these insecticidal paints and coatings the insecticide is of low solubility in the film-forming material. It is assumed that the mechanism of prolonging their toxicity consists essentially in the formation of a supersaturated solution, which crystallizes at the film surface only. This crystallization lowers the concentration of insecticide in solution at the film surface and results in a diffusion of insecticide from the body of the coating to this surface. If we are dealing with a metastable equilibrium such as exists in supersaturated solutions, a scratch or a blow may cause crystallization within the coating, and the slow diffusion of insecticide to the surface will stop and the toxicity of the film will quickly drop. If the surface becomes case-hardened with time, as do many paints and coatings, this diffusion process can no longer take place and again the toxicity of the surface quickly drops.

Suitable Properties of Chlorinated Polyphenyls.—It has been found after a number of trials that a mixture of chlorinated terphenyls available commercially appears to have the physical properties that make it suitable as a film-forming carrier for lindane. This material is produced by the pyrolysis of benzene to yield a mixture containing 80 per cent of biphenyl and 20 per cent of isomeric terphenyls, separation of the terphenyl fraction, and chlorination until a 60 per cent chlorine content is attained. This material is available as Aroclor 5460 and is inexpensive in bulk quantities. It has been safely used for a variety of industrial purposes. However, as a precautionary measure pharmacological studies should be made to determine possible toxicity.

The properties of this product that make it particularly suitable are as follows:

(1) It is a good solvent for lindane, and thereby contributes to the lowering of its vapor pressure and prevents its crystallization.

(2) It is inert, resistant to oxidation, nonflammable, and does not afford a medium for fungus growth. Once the film has been deposited and the solvent evap-

[1] Presented at the meeting of the American Association of Economic Entomologists at Philadelphia, Pa., December 15–18, 1952.

orated, no further change in the physical properties of the film is to be expected.

(3) When properly applied, a 1:1 or a 1:2 mixture of lindane and chlorinated terphenyls provides a surface that is slightly tacky. Insects passing over such a surface appear to pick up the insecticide more readily than when they travel across a hard surface. Thus, when lindane is incorporated in a vinyl-type polymer, a clear transparent film results but because of the surface hardness the insect toxicity is quite low.

DECREASED VOLATILITY OF LINDANE IN MIXTURES WITH CHLORINATED TERPHENYLS.—The rate of volatilization of lindane at a given temperature is a function of its vapor pressure, the surface area available for evaporation per unit mass, and the concentration of lindane in the air surrounding the deposit. The last factor depends largely on the air exchange in the area treated.

The reduction in vapor pressure in lindane-chlorinated terphenyl mixtures accounts in part for the extended life of the material. Of importance too is the decrease in surface area per unit mass of lindane. The relatively large surface associated with lindane crystals is no longer available for vaporization. Instead evaporation takes place from a relatively smooth film having considerably less exposed surface.

In contrast to crystallization from a supersaturated film, it is the evaporation of lindane that creates the lack of balance in concentration that keeps lindane diffusing to the surface from the body of the coating. Thus, higher concentrations of insecticide can be utilized completely and longer lasting residues are obtainable.

COMPARATIVE TOXICITY OF LINDANE AND LINDANE-CHLORINATED TERPHENYL MIXTURES.—In previous tests we compared the effectiveness against the American cockroach, *Periplaneta americana* (L.), of deposits of 100 mg. of lindane per square foot with and without 200 mg. of chlorinated terphenyls on aluminum surfaces (Sullivan & Hornstein 1953). Lindane alone gave a 36 per cent kill after 30 days, a 3 per cent kill after 60 days and no kill at the end of 90 days. The lindane-chlorinated terphenyl mixture still gave 80 per cent kill at the end of 90 days. Tsao *et al.* (1953) obtained similar results against house flies, *Musca domestica* L. On masonite, a porous surface, similar deposits gave only about a 20 per cent kill of American cockroaches after 10 days. Other porous surfaces, such as carpeting and plywood also gave poor results when lindane or lindane-chlorinated terphenyl mixtures were applied.

Our knowledge of the ability of lindane-chlorinated terphenyl mixtures to withstand outdoor weathering is limited. However, the following experiment is of interest. A low-pressure aerosol containing 5 parts each of lindane and chlorinated terphenyls, 40 parts of methylene chloride and 50 parts of *Freon-12* (by weight) was sprayed on the leaves of a small willow tree and subjected to the summer weather conditions prevailing at Beltsville, Maryland. At the end of 30 days a leaf sample was found on analysis to contain 250 micrograms of lindane per square inch. There were no obvious ill effects on the leaves. At the end of 60 days, another leaf sample contained about 200 micrograms of lindane per square inch. At the end of 70 days flies caged around a portion of a treated branch showed 90 per cent mortality and all those on untreated check branches were alive.

Although the fumigating effect of lindane vapors is materially cut down by the lowered rate of vaporization, it is by no means eliminated. Two weeks after lindane chlorinated terphenyl mixtures were painted on the inside of a large glass vessel 50 per cent of caged flies not in contact with the treated surface were killed after a 10-minute exposure.

METHODS OF APPLICATION TO POROUS SURFACES.—We have tried in several ways to obtain better surface coatings on porous materials and have selected unpainted plywood as a typical porous surface for test purposes.

Wetting the surface down with water and then applying as a spray a solution of lindane and chlorinated terphenyls in a low-boiling solvent appears promising. The water prevents the oil from wetting and therefore penetrating the porous surface, and the solvent quickly evaporates to leave a surface deposit of lindane-chlorinated terphenyls.

Pressurized sprays containing low-boiling solvents give good surface deposits. By adjustment of the concentration of a very volatile solvent, such as methylene chloride, in the pressurized-

spray formulation, most of the solvent will evaporate before the lindane-chlorinated terphenyl mixture reaches the surface. The highly viscous particles of this mixture will then have little tendency to penetrate into the porous material.

The lindane-chlorinated terphenyl mixture may be precipitated out of solution just as it hits the surface. A nearly saturated solution of this mixture in acetone-water is prepared. The surface to be treated is wetted down with water. In this instance it is not the repellency of the oil and water, but the solubility of the acetone in water that gives the desired result. The water precipitates the lindane-chlorinated terphenyl mixture out of the acetone solution. After evaporation of the acetone and water, the lindane-chlorinated terphenyl mixture will be left as a spotty but adherent deposit; however, for many purposes, where appearance is not of prime importance, this may prove a useful method of application.

A homogenized suspension of a xylene solution of lindane and chlorinated terphenyls in water also gave promising results. To obtain a fairly stable homogenized suspension, a xylene solution having a specific gravity of 1 was prepared by adding 15 parts each of lindane and chlorinated terphenyls to 60 parts of xylene (all parts by weight). The closer the densities of the mutually insoluble phases the more stable will be the homogenized suspension. This solution was then homogenized with water so that the final suspension contained about 2 per cent each of lindane and chlorinated terphenyls and a water-to-xylene ratio of about 10 to 1. When such a homogenized suspension is sprayed on a surface, it has a tendency to break quickly. Again the initial repellency of oil and water appears to give a good surface coating before much of the insecticide penetrates. This phase of the work is being continued. The surface deposits made as described appear to be heavier than those obtained by direct application of solutions or emulsions.

LINDANE VAPOR PRESSURE IN MIXTURES WITH CHLORINATED TERPHENYLS.—The lindane vapor pressure in various mixtures of lindane and chlorinated terphenyls has been measured (table 1). The lindane was recrystallized from 95 per cent ethanol and had a melting point of 112.5°C. The chlorinated terphenyl was the same product used in the previous tests.

The mixtures were prepared by dissolving the desired amount of lindane and chlorinated terphenyls in acetone. Wads of glass wool were dipped in the solution, then removed and air-dried for 48 hours.

The apparatus consisted of a train having in series a drying bottle filled with anhydrous calcium sulfate, two gas-saturation bottles with fritted glass discs through which the air was pulled and packed with the coated glass wool, an alumina column for adsorbing lindane, a diaphragm-type pump, and a calibrated gas meter. The apparatus was adjusted so that 1 cubic foot of air per hour was pulled through the train. At the completion of the run the lindane adsorbed on the alumina was eluted with acetic acid and the lindane determined colorimetrically (Hornstein & Sullivan 1953).

Table 1.—Vapor pressure of lindane in mixtures with chlorinated terphenyls at 25° C.

Lindane-Chlorinated Terphenyl Ratio		Volume of Saturated Air Sample (Cubic Feet)	Vapor Pressure (Microns)	
Weight	Mole		Measured	Theoretical
1:0	1:0	2.5	0.059	—
1:2	1:1.6	4.0	.029	0.023
1:5	1:4.0	5.0	.017	.012
1:10	1:7.9	6.0	.0073	.0067

The vapor pressures were calculated from the results as described by Thomson (1949). The theoretical vapor pressures were calculated on the assumptions that the chlorinated terphenyl had a molecular weight of 368 and that the vapor pressure of lindane was proportional to the mole fraction of lindane in the film.

SUMMARY.—Lindane residues can be made to last longer and look better if the lindane is applied in chlorinated terphenyl coatings. The vapor pressure of lindane in these films is lowered, but the fumigating action of lindane is not eliminated.

A general method of prolonging the residual effectiveness of volatile insecticides by preparing concentrated solutions in chlorinated polyphenyl film-forming materials has been described.

An attempt has also been made to apply insecticides on porous surfaces in a manner designed to minimize absorption.

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Methyl Bromide Fumigation of Soil for Destruction of White-Fringed Beetle Larvae

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The white-fringed beetle (*Graphognathus* spp.) is now known to occur in eight Southern States. The larvae are present in the soil throughout the year (Young & App 1939). Tests for control measures led not only to the use of methyl bromide to fumigate nursery stock and potting soil under confinement (Hawkins 1939, Livingston 1940) but also to the fumigation of soil areas *in situ*.

Use of methyl bromide and of carbon disulfide in quarantine work was first approved by this Bureau in January 1942 (BEPQ 503, 4th rev.) largely on the basis of tests made at Monroeville, Alabama (Livingstone & Swank 1942).[1] The approved treatment of soil plots and plunging beds provided for an application of methyl bromide at the rate of 4.7 ml. per square foot (7 ml. per 1.5 square feet injected 6 inches into the soil at points 15 inches apart each way. It further provided that the fumigated area should be covered with asphalt builders' paper for 6 days at soil temperatures at the 6-inch level between 45° and 62°F., or for 4 days at temperatures above 62°. It was considered impractical to reduce the permissible minimum soil temperature below 45°, for as the 40° boiling point of methyl bromide was approached this fumigant volatilized less readily and ice crystals from soil moisture were formed which obstructed orifices in the injector. Subsequent to this approval, testing was continued first at Gulfport, Mississippi, and later at Burgaw, North Carolina, in an attempt to improve the treatment schedules and reduce their cost.

METHODS OF APPLICATION.—Technical methyl bromide was applied with a specially built injector (Easter & Dunn 1942) which delivered a fixed amount of 7 ml. per injection. Because the output was not adjustable, it was necessary to vary spacings between injections in order to apply different dosages per square foot. An applicator suitable for injecting small measured amounts in rapid succession is difficult to make, because of the necessity for a closed system capable of retaining vapors under pressure. This system must also include a quick-acting two-way valve. Such a valve permits liquid methyl bromide to pass from storage into the injector chamber while its outlet is closed; then the inlet is closed and the outlet opened so that the charge can escape into the soil through the hollow injection needle. A pressure gauge shows when the chamber is filled or emptied. Pressures up to 90 p.s.i. have been used.

To obviate the mechanical inconveniences of a closed system, volatile liquid vehicles having boiling points above normal outdoor temperatures were tested. Aqueous emulsions were unsatisfactory, but certain organic solvents were found suitable. A proprietary product containing 10 per cent of methyl bromide and 90 per cent of ethylene dichloride was tested

[1] Most of this work was done by G. R. Swank; later he and E. E. Rogers continued this work and made preliminary tests on the field use of methyl bromide solutions.

extensively. Later a slightly more effective mixture was used in which carbon tetrachloride replaced one-fourth of the ethylene dichloride. The manufacturer discontinued the former mixture in favor of the latter. Since the difference in effectiveness between the two mixtures seems to be insufficient to warrant presentation of separate results, data on their use are summarized together.

These solutions were applied with a proprietary soil injector of adjustable output so that different dosages of methyl bromide could be applied at constant spacing as well as a constant dosage at different spacings. This applicator consisted of a 1-gallon storage tank and an outlet cylinder the lower end of which terminated in an injection point. The output of the cylinder was determined by the length of stroke of its piston. This stroke was controlled by an adjustable collar on the exterior portion. Fluid entering the cylinder was retained by a spring-powered ball valve until expelled by a manual stroke of the piston.

Although it was recognized that a staggered pattern of injections required less fumigant (Taylor 1939), a regular pattern was usually selected because it was more convenient.

TESTING PROCEDURE.—Most of the tests were made in fields containing natural populations of larvae. When such fields could not be found, soil areas were infested artificially by dropping larvae singly into dibbled holes 2 inches apart. These holes were then filled with soil, the area was sprinkled with water, and a week was allowed for the larvae to establish themselves.

Tests were made in soils of different type, tilth, and moisture content. It was soon shown that larvae in loose or cultivated light loam with moderate moisture were killed by much lower dosages than those in undisturbed compact, moist, clay or muck soils; therefore most tests were made in undisturbed sites. Circumstances unfavorable for successful fumigation were chosen when available so as to incorporate a safety factor, in anticipation of field conditions.

Plots to be fumigated were laid off square with a measuring tape, corner stakes were set, and row-marker stakes spaced along two opposite sides. The tape was then stretched between two stakes marking a row, and the injections were made at selected intervals along the tape, which was then moved to the next row. Injection holes were closed immediately with a hoe handle or shoe heel.

Technical methyl bromide was applied at various spacings and at soil temperatures at the 6-inch level ranging from 40 to about 80°F. The solutions of methyl bromide in ethylene dichloride and in ethylene dichloride plus carbon tetrachloride were applied at about the same range of temperatures but at different spacings.

Each plot was covered immediately with strips of asphalted builders' paper, the seams were lapped at least 4 inches, and all seams and outside edges were weighted with a continuous band of soil. The paper covering remained on the plots for different periods in early tests (see table 2), but standard times of 4 days for methyl bromide and 7 days for its solutions were selected. In some preliminary tests the soil was sprinkled in an attempt to make a water seal and avoid the trouble and expense of a paper cover, but then there was complete mortality of larvae deep within the soil but not near the surface.

At the end of the treatment time the cover was removed and the larvae were recovered from the central portion of the plot by digging out the soil with a shovel and raking through it carefully. All larvae were recorded, and any showing life were placed on moist sand in clay pots and kept in a controlled cabinet at approximately 85° F. and 100 per cent relative humidity. Those that dug into the sand were recorded as survivors. This is the usual mortality test for white-fringed beetle larvae (Livingstone & Swank 1942).

RESULTS.—The results of the tests with technical methyl bromide are summarized in table 1 and of those with the methyl bromide solutions in figures 1 to 3. In these figures solid dots represent plots where no survivors were found and hollow dots plots with one or more survivors. The recommended dosage schedules were shifted to the right of the mortality line to incorporate a safety factor of slightly excessive dosages to allow for adverse field conditions. These three figures represent 13 plots from which 301 survivors occurred in 7,719 specimens found.

It is evident from these results that

Table 1.—Summary of data on soil-plot fumigation with technical methyl bromide for control of white-fringed beetle larvae.

Spacing of Injections	Soil Temperature at 6 Inches	Dosage per Square Foot[1]	Plots	Specimens	
				Recovered	Survived
Inches	*° F.*	*Milliliters*	*Number*	*Number*	*Number*
18 by 18	40–44	4.0	1	37	0
		4.2	2	80	2
	45–49	3.0	1	32	2
	50–54	2.9	1	43	0
		3.4	1	5	0
		4.5	1	29	0
	55–59	3	1	38	0
		3.7	1	43	0
	60–64	2.7	2	80	0
	65–69	2.7	1	66	0
	70–74	1.6	2	131	0
		3.1	1	80	0
		4.2	1	152	0
	75–79	2.4	2	134	0
		3.4	2	68	0
	80–85	2.5	2	27	0
21 by 21[2]	40–44	3	2	27	0
	45–49	2.2	1	24	2
		3	1	33	1
	50–54	1.8	1	53	1
		2.3	1	25	0
		2.8	1	68	0
	55–59	3.3	1	54	0
		2.8	1	47	7
	60–64	2.0	2	40	1
		2.7	1	44	0
	65–69	2.0	1	33	0
		2.4	1	10	0
	70–74	2.3	2	60	0
		2.6	2	66	0
	75–79	1.8	2	69	0
	80–85	1.7	2	36	0
24 by 24	40–44	2.3	2	105	3
		4.7	1	24	2
	45–49	2.3	1	77	0
		3.3	1	48	2
	50–54	1.3	1	67	5
		1.7	1	30	0
		2.1	1	129	0
	55–59	1.7	1	28	0
		2.1	1	26	4
	60–64	1.5	5	362	27
	65–69	1.5	1	100	0
		1.8	1	13	0
	70–74	1.6	4	248	2
		1.9	9	472	4
	75–79	1.3	1	50	0
		1.8	1	50	0
	80–85	1.4	2	42	0
		1.8	2	38	0

[1] The output of the injector varied slightly with the air temperature, the air pressure in the storage cylinder, and by the use of a solder block fitted into the chamber of the two-way valve of the injector.

[2] Includes data from 18 by 24 inch spacings since the areas are so nearly the same.

at the higher soil temperatures the dosages could be reduced. With methyl bromide injected in increments of 7 ml., the rate per square foot of soil surface would be 4.7 ml. for 12- by 18-inch spacing, 3.1 ml. for 18- by 18-inch spacing, 2.4 ml. for 21- by 21-inch spacing, and 1.8 ml. for 24- by 24-inch spacing. The rate of 4.7 ml. per square foot had previously been proved adequate at temperatures as low as 45°F. (Livingstone & Swank 1942). In the results reported in table 1 the rate of approximately 3.1 ml. per square foot at 18- by 18-inch spacing gave complete mortality at 50° and above. The rate of 2.4 ml. per square foot at 21- by 21-inch spacing produced complete mortality at about 65° and above. The rate of 1.8 ml. per square foot at 24- by 24-inch spacing produced complete mortality at 75° and above.

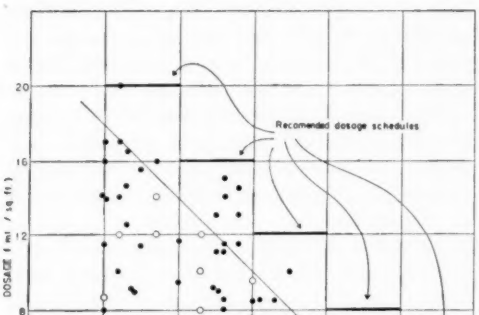

FIG. 1.—Summary of data of soil-plot fumigations with methyl bromide solutions at 12 by 12 inch spacing.

The methyl bromide solutions followed the same pattern. At the 12- by 12-inch spacing (Fig. 1) there were no survivors above a dosage-mortality line from 18 ml. per square foot at 40°F to 2 ml. at 80°. At the 15- by 15-inch spacing (Fig. 2) the dosage-mortality line increased to a range from 18 ml. per square foot at 50° to 6 ml. at 80°, and even with this increase there was one exception in a test at 55° soil temperature. At the 18- by 18-inch spacing (Fig. 3) the dosage-mortality line ranged from 20 ml. per square foot at 50° to 8 ml. at 80°.

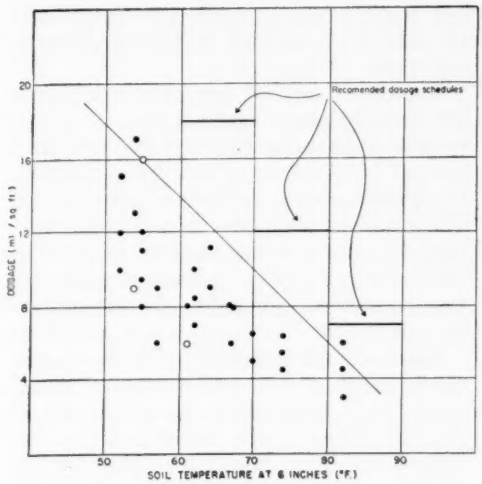

FIG. 2.—Summary of data of soil-plot fumigations with methyl bromide solutions at 15 by 15 inch spacing. Some data from 12 by 18 inch spacings are included.

The results of the preliminary tests in which replicate plots were uncovered after different time intervals are summarized in table 2. When the duration was too long, many larvae were lost as a result of decomposition, especially in warm weather, and the landowner was inconvenienced through inability to work or use his land. When the duration was too short, larger amounts of fumigant were needed and plants sensitive to methyl bromide, such as Coral Bell azaleas, were killed if planted immediately.

Similar tests in which all plots showed 100-per cent mortality of beetles lend support to the conclusion that insecticidal activity is mostly completed within the first few days. The cover periods finally selected, 4 days for technical methyl bromide and 7 days for the solutions, permitted reasonably complete fumigation. If the mortality was less that 100 per cent in subsequent standard treatments, it was presumed to be due to insufficient dosage rather than to insufficient exposure time.

SELECTION OF QUARANTINE TREATMENTS.—On the basis of the data summarized above the white-fringed beetle administrative instructions of 1942 were revised in 1948[2] to permit the use of technical methyl bromide at reduced dosages or of methyl bromide solutions, with

[2] (BEPQ 503, 4th rev.)

Table 2.—Effect of varying the time a paper cover was left on soil plots fumigated with 10-per cent methyl bromide solutions.

SPACING OF INJECTIONS, INCHES	DOSAGE PER SQUARE FOOT, MILLILITERS	TIME PLOTS WERE COVERED, DAYS	SOIL TEMPERATURE AT 6 INCHES, ° F.	PER CENT MORTALITY
12 by 12	3	8	69.0	90
		15	69.5	98
	4.5	7	68.0	97
		14	74.5	100
	6	4	69.0	95
		15	69.0	96
	11	8	84.5	98
		16	71.5	100
18 by 18	5	1	78.5	87
		2	78.5	91
	5	4	71.5	46
		7	72.0	70
	5	4	71.5	93
		7	72.0	88
	10	4	66.5	97
		7	66.5	97

both schedules closely adjusted to soil temperatures. The schedules selected are given below.

SOIL TEMPERATURE (° F.) AT 6 INCHES	MILLILITERS PER INJECTION	SPACING OF INJECTIONS[1] (INCHES)	MILLILITERS PER SQUARE FOOT
Technical methyl bromide (covered 4 days)			
45–55	7	15 by 15	4.7
55–65	7	18 by 18	3.1
65–75	7	21 by 21	2.4
75 and above	7	24 by 24	1.8
10-per cent methyl bromide solution (covered 7 days)			
40–50	20	12 by 12	20
50–60	16	12 by 12	16
60–70	12	12 by 12	12
70–80	8	12 by 12	8
80 and above	5	12 by 12	5

[1] These areas are approximately equivalent to 1.5, 2.25, 3, and 4 square feet, respectively.

When these dosage schedules were recommended, only one type of applicator was available for dispensing technical methyl bromide and it had a fixed delivery rate. Reductions in dosages, therefore, could only be made by increasing the spacing. This procedure entailed an inefficient use

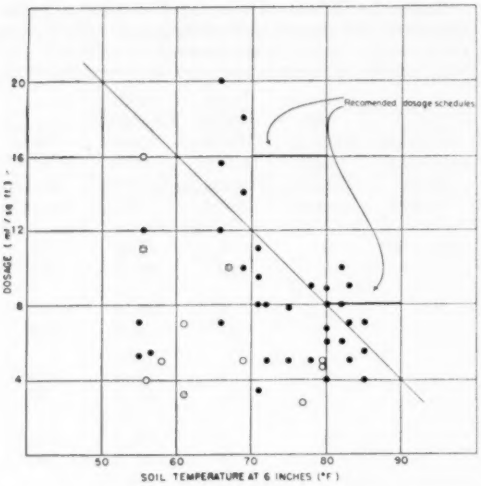

FIG. 3.—Summary of data of soil-plot fumigations with methyl bromide solutions at 18 by 18 inch spacing.

of fumigant. When methyl bromide solutions were recommended, an injector with a variable output, which was readily adjusted, was available. The data plainly showed that dosage reduction at the 12- by 12-inch spacing was more economical than a constant dosage at greater spacing.

SUMMARY.—Larvae of the white-fringed beetle (*Graphognathus* spp.) occur in the soil of eight Southern States throughout the year. A quarantine treatment for soil fumigation with methyl bromide (and carbon disulfide) was approved in 1942, but testing was continued in an attempt to reduce the dosage and to find better materials.

Technical methyl bromide has such a low boiling point (40°F.) that a special type of applicator with a closed system is needed. Therefore solutions of methyl bromide in ethylene dichloride or ethylene dichloride plus carbon tetrachloride were tested because of the ease of application with a simple, open, adjustable injector. Procedures are given for the use of both materials.

Natural and artificial infestations were used in soils of different types and conditions. Test plots were covered with asphalt builders' paper to retard gas loss. After fumigation larvae were dug by hand and given a chance to resume activity.

The results showed that the dosage schedule for methyl bromide adopted in 1942 could be reduced by increasing the dimensions of the spacing pattern. Ten-per cent solutions were found effective and convenient for soil fumigation, but to require a longer time. The action of both materials was directly related to temperature and nearly completed within the first few days. Fumigated soil should be allowed to aerate before sensitive plants are placed in it.

Approved quarantine-treatment schedules for methyl bromide and its 10-per cent solutions are given.

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The Relative Toxicity to House Flies of the Methyl and Ethyl Analogs of Allethrin

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In a program of work seeking synthetic compounds of high toxicity to insects, the relationship of chemical structure to toxicity is of secondary interest. Therefore, chemists of the Bureau of Entomology and Plant Quarantine have not attempted to prepare all compounds in a series of closely related esters of the type of allethrin. Believing that the presence of at least one double bond in the side chain in position 2 of the nucleus of the cyclopentenolone component of such esters is of marked importance in the toxic action of these compounds, they have emphasized the preparation of compounds with unsaturated side chains in this position. Evidence of the soundness of this opinion has been found in comparative toxicity tests with such compounds. The hydrogenation of the double bonds in the side chain in this position in pyrethrin I (Gersdorff 1947) and of the double bond in the side chain in the natural acid ester of *trans*-cinerolone or its 3-butenyl isomer (Gersdorff 1949a) resulted in compounds of relatively low toxicity.

Japanese workers in this field have held a similar opinion (Inoue *et al.* 1951). However, high toxicity cannot be ascribed solely to this unsaturated structure, since many analogs with a double bond have been found both in the United States and in Japan to have relatively low toxicity. Therefore, the Japanese chemists have prepared some esters with alkyl—that is, saturated side chains (Katsuda *et al.* 1951). These esters differ structurally from allethrin only in the nature of these side chains; saturation of the allyl side chain in allethrin forms the propyl analog. Several of the esters, when tested against house flies, *Musca domestica* L., (Inoue *et al.* 1951) caused mortality as high or nearly as high as did allethrin in the few tests made for this measurement, the criterion for comparative effectiveness being median knockdown time. Therefore, two of these alkyl esters were prepared in this Bureau, and a study was undertaken to determine their relative potency by a dosage-response procedure in which the response measured was mortality.

Materials.—The two esters were the methyl[1] and ethyl[2] analogs of allethrin, prepared according to the general procedure described by Schechter *et al.* (1949); the samples used were practically pure. A distilled sample of allethrin, analyzing 95 per cent by the hydrogenolysis method, and two samples of pyrethrins from different sources were used as standards of comparison. Pyrethrin I and cinerin I comprised 53 per cent of the total pyrethrins of the first sample and 52 per cent of the second when analyzed by the mercury-reduction method.

Procedure.—These materials were dissolved in refined kerosene and diluted with the same solvent to form sprays for each at four concentrations selected according to preliminary tests.

Knockdown and mortality of house flies were determined in tests by the Campbell turntable method. Since the alkyl esters were prepared seven months apart and were tested immediately after preparation, the tests were made in two series, standard materials being included in each. Six replications were made, all sprays in each series being tested simultaneously on each population of flies. Approximately 100 flies were used in each test in the first series and approximately 90 in the second. The average age of flies in all populations was 2 to 3 days.

To evaluate relative toxicity and determine the precision of the estimates, the mortality data were subjected to probit analysis as described by Finney (1952).

Mortality and Knockdown.—The mortality data are summarized in table 1. Knockdown of flies in 25 minutes was complete for all sprays except that with allethrin at 0.25 mg. per milliliter. With this spray 90 per cent of the flies were knocked down in the first series and 98 per cent in the second.

Evaluation of Relative Toxicity—The data in the first series could not be

[1] Prepared by Yuh-Lin Chen and W. F. Barthel.
[2] Prepared by M. S. Schechter and Nathan Green.

fitted by parallel lines. Not only is this indicated by the slopes of the individual lines and their calculated errors but, when the data are fitted with parallel lines, an analysis of chi-squares shows that departure from parallelism is highly significant. However, the differences in slope are not great. The slope for the methyl analog is 2.04 ± 0.19, for allethrin 3.30 ± 0.22, and for pyrethrins 2.94 ± 0.10 probits per unit log concentration.

Table 1.—Mortality of house flies caused by the methyl and ethyl analogs of allethrin in comparison with allethrin and pyrethrins. All values are the means of six replications.

Material	Concentration	Mortality in 1 Day
	Mg. per Ml.	*Per Cent*
Series 1:		
Methyl analog	32	91.6
	16	77.8
	8	62.2
	4	30.7
Allethrin	2	89.8
	1	64.0
	0.5	28.8
	0.25	3.4
Pyrethrins	7.448	91.5
	3.724	67.2
	1.862	33.5
	0.931	9.8
Series 2:		
Ethyl analog	16	92.5
	8	90.4
	4	60.9
	2	31.9
Allethrin	2	84.9
	1	68.2
	0.5	27.2
	0.25	6.9
Pyrethrins	7.474	85.5
	3.737	61.8
	1.869	32.4
	0.934	11.8

Too much emphasis should not be put on the slope of the methyl analog line because, in the authors' opinion, four points are insufficient for a critical determination of slope and furthermore markedly dissimilar ranges of mortality levels may have an unfavorable effect on the estimation. Unfortunately, the lowest mortality level reached with the methyl analog was not so low as with the other materials. A more thorough examination is especially needed for a precise estimation of slope when there is heterogeneity between populations of insects, a probability under the conditions in replicated tests such as in this study. However, for practical purposes with such similar compounds comparison of toxicity at the median lethal concentration will suffice, even when parallelism of the regressions has not been demonstrated in the tests.

In many comparisons by this method against house flies the slope of the allethrin line has been demonstrated more often than not to be slightly greater than that of the pyrethrins line. In some, as in this series, a slope appearing to be greater has not been so demonstrated when the data were examined statistically, but in none has the slope of the allethrin line been found to be lower than that of pyrethrins. For these reasons it was thought best to use the equations of the statistically fitted individual lines for the subsequent estimations for all three compounds.

In the second series the data could have been represented by parallel lines. The slopes of the individual lines are for the ethyl analog 2.34 ± 0.44, for allethrin 2.88 ± 0.30, and for pyrethrins 2.49 ± 0.10. Again the slope for allethrin has not been demonstrated statistically to be greater than that for pyrethrins. However, the equations used for the subsequent comparisons in this series were, in conformity with the analysis of series 1, those of the individually fitted lines.

Actually, in these studies—and this is true generally in similar studies by this method—the ratios of toxicity are not materially different if parallel lines are fitted. Had the data been fitted to parallel lines, the common slope in the first series would have been 2.71 ± 0.09 and in the second, 2.56 ± 0.17.

Heterogeneity factors were used for variances for the methyl analog (4.03) and allethrin (3.70) in the first series and for the ethyl analog (15.84) and allethrin (7.38) in the second. None was required for pyrethrins in either series. Had the data been fitted to parallel lines, the generalized heterogeneity factors would have been 2.33 and 7.75 for the respective series.

The equations showing the regression of mortality, expressed in probits, on concentration in milligrams per centiliter, expressed in logarithms, are as follows:

Series 1:	
Methyl analog	$Y=2.039X+1.307$
Allethrin	$Y=3.297X+2.046$
Pyrethrins	$Y=2.938X+0.847$
Series 2:	
Ethyl analog	$Y=2.342X+1.544$
Allethrin	$Y=2.876X+2.431$
Pyrethrins	$Y=2.489X+1.389$

From these equations the median lethal concentrations (LC-50's) were calculated. Relative toxicity was calculated as the inverse ratio of LC-50's. The estimations together with their standard errors are given in table 2.

To confirm the statement that the ratios of toxicity would not be materially different if parallel lines were fitted, this procedure was also followed, and the LC-50's and their ratios, together with the errors, were determined from the generalized equations. The LC-50's, in the same order as given in table 2, were 7.10 ± 0.29, 0.792 ± 0.031, 2.60 ± 0.10, 3.10 ± 0.26, 0.785 ± 0.063, and 2.82 ± 0.21. The respective toxicities relative to pyrethrins were 0.37 ± 0.02, 3.28 ± 0.18, 0.91 ± 0.10, and 3.59 ± 0.40. It is apparent that the differences in the estimations by the two procedures are negligible.

Table 2.—Toxicity to house flies of the methyl and ethyl analogs of allethrin as compared with allethrin and pyrethrins.

MATERIAL	LC-50	RELATIVE TOXICITY
	Mg. per ml.	
Series 1:		
Methyl analog	6.47 ± 0.49	0.40 ± 0.03
Allethrin	0.787 ± 0.034	3.29 ± 0.18
Pyrethrins	2.593 ± 0.090	1.0
Series 2:		
Ethyl analog	2.99 ± 0.44	0.94 ± 0.14
Allethrin	0.782 ± 0.054	3.61 ± 0.27
Pyrethrins	2.825 ± 0.080	1.0

DISCUSSION.—The methyl and ethyl analogs of allethrin are thus shown to be, respectively, 0.40 and 0.94 as toxic to house flies by this method as pyrethrins. Relative to allethrin the ratios are 0.12 and 0.26. Here, then, are two compounds possessing considerable toxicity with no double bond in the substituent in position 2 of the allethrolone component of the ester. This finding, together with the finding of relatively low toxicity for two analogs with the double bond in a side chain in this position (3-methyl-2-butenyl, Gersdorff 1949a; 3-chloro-2-butenyl, Gersdorff & Mitlin 1951) indicate that the presence of such a double bond is in itself not essential for toxicity.

Inoue *et al.* (1951) included in their study tests as space sprays with the propyl and *n*-butyl as well as the methyl and ethyl analogs. Although they compared insecticidal effectiveness by measurement of median knockdown time, they reported mortalities from no more than two tests at one concentration with about 25 flies per test for each material. Such meager information does not permit the quantitative comparison of toxicity from the standpoint of lethality, but mortalities obtained with all four alkyl analogs were relatively high as compared with the mortality obtained with allethrin.

Coincident with another change in chemical structure, the presence of a double bond in this side chain may be of great importance; for example, of three *d-trans* acid esters of cyclopentenolones with a 4-carbon side chain, those with the 2-butenyl and 3-butenyl side chains were, respectively, 8.8 and 3.7 as toxic as the ester with the *n*-butyl side chain (Gersdorff 1949a). Indeed, the occurrence of a triple bond in the 4-carbon side chain was also of importance; the mixture of *cis* and *trans dl* acid esters with the 2-butynyl side chain was 0.73 as toxic as natural pyrethrins (Gersdorff & Mitlin 1951), and therefore about 4.3 as toxic as the above *n*-butyl compound, since the latter was 0.17 as toxic as pyrethrins. A ratio of 8.6 to the comparable acid ester of the *n*-butyl cyclopentenolone would therefore be indicated, if based on the ratio previously found by this method for two pairs of isomers with a similar configurational relationship in the acid component (Gersdorff 1949b; Gersdorff & Mitlin 1952). The presence of two double bonds in this side chain in the case of pyrethrin I is apparently of great importance, for this ester was found to be more than 16 times as toxic as its corresponding saturated compound, tetrahydropyrethrin I.

An unsaturated side chain in position 2 of the cyclopentenolone nucleus of pyrethroids is not essential, then, to relatively high toxicity, but where comparison of corresponding esters is possible dehydrogenation of an alkyl side chain is accompanied by an increase in toxicity of the ester.

The estimations of the ratio of toxicity of allethrin to pyrethrins (3.29 and 3.61) were higher than is usually obtained by this method. Of 13 previous estimations 9 fell between 2.55 and 3.24.

SUMMARY.—The relative toxicity to house flies, *Musca domestica* L., of the methyl and ethyl analogs of allethrin was evaluated by the turntable method in comparison with allethrin and pyrethrins.

The methyl analog was 0.12 as toxic as allethrin and 0.40 as toxic as pyrethrins.

The ethyl analog was 0.26 as toxic as allethrin and 0.94 as toxic as pyrethrins.

Knockdown of flies was complete for the sprays containing the analogs at the concentrations used.

From this study and a further consideration of previous work the following conclusion is drawn with respect to relationship between structure and toxicity: An unsaturated side chain in position 2 of the cyclopentenolone nucleus of pyrethroids is not essential to relatively high toxicity, but where comparison of corresponding esters is possible dehydrogenation of an alkyl side chain is accompanied by an increase in toxicity of the ester.

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Control of the Gulf Wireworm in Sweetpotatoes in Alabama

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The Gulf wireworm, *Conoderus amplicollis* (Gyll.), was first recognized as a pest in the United States in Baldwin County, Alabama, in 1927 (Cockerham & Deen 1936). At that time it was reported injuring sweetpotatoes in southern Alabama. The insect has become a major pest of sweetpotatoes throughout the state, and it is probably the most important subterranean insect pest of sweetpotatoes in Alabama. Cockerham & Deen (1936) reported that this insect had a one-year life cycle in Alabama, the larval period being approximately 315 days.

Although crop failure rarely, if ever, occurs from the injury inflicted to sweetpotatoes by this insect, the punctures resulting from the feeding by the wireworms mar the appearance of the potatoes and lower their market value. Also, these punctures afford a means of entrance for secondary infections such as soil and storage rots, and these rots may result in tremendous losses of stored potatoes. Field experiments were conducted during 1951 and 1952 in Alabama on the control of the Gulf wireworm attacking sweetpotatoes. The results of these tests are reported in this paper.

PROCEDURE.—In 1951, field tests were conducted at four locations in Alabama. These were Ashford, Auburn, Clanton, and Cullman. Each test involved introducing insecticidal compounds into the soil in row treatments approximately 2 weeks prior to the setting of the potato slips. The treatments were replicated four times in randomized blocks. The plots

Table 1.—Effect of various treatments on control of wireworms attacking sweetpotatoes, 1951.

Treatment	Pounds per Acre	Per Cent Undamaged Potatoes at Different Locations[1]									
		Ashford		Auburn		Clanton		Cullman		Mean	
Check		52	46.2[2]	42	40.4	31	33.8	15	22.8	35	35.8
Chlordane	2	93	74.7	81	64.2	21	27.3	20	26.6	54	48.2
Lindane	2	96	78.5	86	68.0	46	42.7	46	42.7	68	58.0
Heptachlor	1	97	80.0	91	72.5	39	38.6	48	43.8	69	58.7
Aldrin	1	99	84.3	82	64.9	37	37.5	48	43.8	66	57.6
Dieldrin	1	98	81.9	80	63.4	38	38.1	44	41.5	65	56.2
Parathion	1	63	52.5	76	60.7	33	35.1	38	38.1	52	46.6
Toxaphene	10	97	80.0	90	71.6	34	35.7	20	26.6	60	53.5
BHC (3% g.i.)	2	92	73.6	88	69.7	42	40.4	58	49.6	70	58.3
Ethylene dibromide	8.2 gal.	62	51.9	93	74.7	47	43.3	30	33.2	58	50.8
Least significant difference (5 per cent level)			14.6		None		None		17.5		11.6

[1] Per cent of total weight.
[2] Angular transformation of percentage to which L.S.D. applies follows each percentage.

consisted of three rows 3.5 feet wide and 30 feet long.

The materials tested were chlordane, lindane, heptachlor, aldrin, dieldrin, parathion, toxaphene, benzene hexachloride, and ethylene dibromide. All compounds except ethylene dibromide were dust formulations and were mixed with the fertilizer prior to applying to the soil. These insecticide-fertilizer mixtures were applied to the open furrow by hand. Ethylene dibromide, a liquid fumigant, was applied to the open furrow from a calibrated jar after the fertilizer had been applied. The furrows were covered immediately after the materials were applied.

Experiments were conducted at Ashford, Clanton, and Cullman in 1952. With the exception of an increase in rates of materials and size of plots, the tests at Ashford and Clanton were the same as in 1951. In several instances the rates of materials were twice that of the rates used in 1951. Plot sizes were increased to five rows 3.5 feet wide and 30 feet long. At Cullman, two additional rates of chlordane, heptachlor, and dieldrin were tested. Otherwise, the test at Cullman was the same as those at Ashford and Clanton.

The sweetpotatoes were harvested approximately 180 days after the insecticides were put into the soil. In 1951, the middle row of each plot was harvested; in 1952 the three inside rows of each plot were harvested. The control and yield data were computed on the marketable potatoes.

All potatoes harvested from the test rows were graded into U.S. number one's, two's and culls. The yield was computed on a per-acre basis by combining the one's and two's. After the potatoes were graded, they were checked individually for wireworm injury. Wireworm injury was divided into three categories: light, moderate, and heavy. The three categories of injury and one where no injury was noted gave the four classes of sweetpotatoes that were considered in computing the per cent injury by treatments.

RESULTS.—Results of the four experiments conducted in 1951 are presented in table 1. In general, wireworm infestations were light over the entire state. Also, the yield of sweetpotatoes was low, an exception being the test at Clanton where the yield was approximately 250 bushels per acre on the test plots. Extremely dry weather during the sweetpotato growing season was presumably the major factor causing low wireworm infestations and reduced yields.

In tests at Clanton and Cullman in 1951, none of the insecticidal compounds gave good wireworm control. However, all compounds except chlordane in the test at Clanton gave some degree of control. Furthermore, in the test at Cullman, all insecticidal treatments except chlordane, parathion, toxaphene, and ethylene dibromide gave significant control. These results indicated that the rates of materials might have been too low to give practical control. At Ashford, all insecticidal treatments except para-

Table 2.—Effect of various treatments on control of wireworms attacking sweetpotatoes, 1952.

Treatment	Pounds per Acre	Per Cent Undamaged Potatoes at Different Locations[1]							
		Ashford		Clanton		Cullman		Mean	
Check		42	40.4[2]	72	58.0	53	46.7	56	48.4
Chlordane	4	75	60.0	88	69.7	66	54.3	76	61.3
Chlordane	6					60	50.8		
Chlordane	8					67	54.9		
Lindane	2	92	73.6	97	80.0	72	58.0	87	70.5
Heptachlor	2	94	75.8	95	77.1	79	62.7	89	71.9
Heptachlor	4					85	67.2		
Heptachlor	8					82	64.9		
Aldrin	2	92	73.6	95	77.1	85	67.2	91	72.6
Dieldrin	2	87	68.9	87	68.9	69	56.2	81	64.7
Dieldrin	4					84	66.4		
Dieldrin	8					86	68.0		
Parathion	2	57	49.0	86	68.0	69	56.2	71	57.7
Toxaphene	10	68	55.5	95	77.1	61	51.3	75	61.3
BHC (3% g.i.)	3	82	64.9	97	80.0	79	62.7	86	69.2
Ethylene dibromide	8.2 gal.	58	49.6	80	63.4	68	55.5	69	56.2
Least significant difference (5 per cent level)			13.6		9.9		10.8		8.9

[1] Per cent of total weight.
[2] Angular transformation of percentage to which L.S.D. applies follows each percentage.

thion and ethylene dibromide were significantly better than the check. All plots receiving insecticidal treatments that gave significant control produced over 90 per cent clean potatoes. All treatments gave good wireworm control in the test at Auburn. No significant differences existed between the treatments and the check due to the extreme variations between replicates of the treatments.

Results of the experiments conducted in 1952 are presented in table 2. In the experiment at Ashford, parathion and ethylene dibromide gave no practical control of wireworms. All other insecticidal compounds significantly reduced wireworm infestations at this location; however, chlordane and toxaphene were less effective than lindane, heptachlor, aldrin, dieldrin, and benzene hexachloride. All treatments except ethylene dibromide resulted in significantly more clean potatoes than the untreated plots at Clanton. The infestation of wireworms was lighter at Clanton in 1952 than at Ashford or Cullman; this is shown by the high percentage of clean potatoes harvested from the untreated check plots.

Results of the experiment at Cullman revealed that the compounds most effective in 1951 were also most effective in 1952. All treatments except chlordane at 4 and 6 pounds per acre, toxaphene, and ethylene dibromide were significantly better than no treatment. Increased rates of chlordane were not significantly better than chlordane at 4 pounds per acre. Heptachlor at 4 and 8 pounds per acre was slightly more effective than heptachlor at 2 pounds per acre, but this difference was not enough to justify higher rates of application. Dieldrin at 8 pounds per acre gave significantly better control than dieldrin at 2 pounds per acre.

Data collected during 1951 and 1952 on the yields from the various plots revealed that the insecticidal compounds had no detrimental effects on the yields of sweetpotatoes.

TASTE TESTS.—Taste tests were conducted in 1951 and 1952 to determine if any of the insecticidal compounds had imparted undesirable flavors to the potatoes. Rodrigues & Gould (1950) and Turner (1950) reported that benzene hexachloride caused off flavors in Irish potatoes. Pepper *et al.* (1947) and Greenwood (1948) reported that they found no off flavors in Irish potatoes harvested from plots treated with benzene hexachloride. No authentic reports on the effect of insecticides on the flavor of sweetpotatoes, plus conflicting reports on flavor effects of Irish potatoes, prompted the instigation of taste tests. These tests were conducted by the Food Processing Laboratory at the Alabama Polytechnic Institute. The potato samples from each

treatment were baked, mascerated and packaged before they were distributed to the six members of the taste panel. Members of the taste panel reported that none of the samples had any undesirable flavors which could have resulted from the insecticidal compounds.

SUMMARY.—Wireworms are among the most important subterranean insect enemies of sweetpotatoes in Alabama. Although crop failure rarely, if ever, results from the injury inflicted on sweetpotatoes by these insects, the appearance of the potatoes is marred, thus lowering their market value. Furthermore, the punctures left in the potatoes afford entrance for secondary infections such as soil and storage rots.

Experiments were conducted during 1951 and 1952 on control of this insect. These experiments involved introducing nine different insecticides into the soil in row treatments approximately 2 weeks prior to setting the potato slips. The materials were chlordane, lindane, heptachlor, aldrin, dieldrin, parathion, toxaphene, benzene hexachloride, and ethylene dibromide.

The potatoes were harvested approximately 180 days after the insecticides were applied to the soil. Wireworm injury was determined by inspecting the potatoes individually. All potatoes harvested from the test rows were inspected for injury and each placed in a category according to the extent of injury. The categories were clean, light, moderate, and heavy damage.

Five compounds, lindane, heptachlor, aldrin, dieldrin, and benzene hexachloride gave good wireworm control over the two-year testing period. Chlordane and toxaphene gave good control in some tests and no control in other tests. Further work is needed with chlordane and toxaphene to determine their effectiveness against wireworms. Parathion and ethylene dibromide gave no practical control of wireworms in these experiments. Taste tests in 1951 and 1952 revealed that the sweetpotatoes harvested from plots receiving insecticidal treatments contained no undesirable off flavors. Yield data indicated that the insecticidal compounds had no detrimental effects upon the yield of sweet potatoes in the treated plots.

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Chemical Control of the Engelmann Spruce Beetle in Colorado

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In 1950 large-scale control measures were undertaken for the control of the Engelmann spruce beetle, *Dendroctonus engelmanni* Hopkins, in Colorado. Orthodichlorobenzene, 1 part by volume to 6 parts of No. 1 fuel oil, was applied to the infested stems of standing trees. The effectiveness of this solution had been demonstrated in small-scale tests during the previous five years. The material is costly, however, and in 1950 was in short supply because of the demands of the Armed Forces. It was also found difficult to transport large volumes of the insecticide over rough terrain of the infested areas.

Simultaneous with the start of this program, experiments were initiated to develop improved methods and materials for the control of the beetle. Tests were

[1] In cooperation with the Colorado A. & M. College, Fort Collins, Colorado.

Table 1.—Effectiveness against the Engelmann spruce beetle of ethylene dibromide emulsions applied to standing trees in July 1950.

Emulsion			Average Number of Live Insects per Sq. Ft. of Bark at Indicated Heights[1]					Relative Per Cent Survival at 5 Feet
				Feet				
Solvent	Per Cent of Water	Ethylene Dibromide (Pounds per 5 Gallons)	Base	5	10	15	18	
Fuel oil	80	0	—	121.7	—	—	—	86.2
		1	—	15.1	—	—	—	10.7
		2	0.5	4.0	45.2	38.6	58.0	2.8
		3	.5	3.9	2.6	63.0	0	2.8
Stoddard	60	0	—	82.9	—	—	—	58.7
		1	—	18.7	—	—	—	13.2
		2	0	6.4	21.0	7.7	25.7	4.5
		3	0	0.6	1.2	23.3	26.0	.4
	80	0	—	50.5	—	—	—	35.8
		1	—	17.8	—	—	—	12.6
		2	0	11.1	27.3	26.3	36.3	7.9
		3	0	1.1	29.7	24.0	25.0	.8
		4	1.3	.9	2.7	26.0	24.0	.6
	90	3	0	7.2	27.2	46.8	69.3	5.1
		4	0	11.5	29.7	105.3	76.4	8.1
Untreated		—	—	141.1	—	—	—	100

[1] Treated trees, 20 samples at 5-foot level and six samples at other levels; untreated trees, 28 samples at 5-foot level.

made to determine whether other fumigant solutions were equally as effective as the orthodichlorobenzene-fuel oil solution in order to provide an adequate supply of insecticide. However, the primary objective was to develop emulsifiable concentrates of insecticides for dilution with water available at points close to infested trees, and thus reduce the cost and difficulties of transportation.

MATERIALS AND METHODS.—Studies were carried on in 1950 and 1951. The field tests were made during the summer and fall at elevations of about 9,500 feet, on the western slope of the Rocky Mountains in Colorado. In the fall other tests were made in the laboratory at Fort Collins.

Table 2.—Effectiveness against the Engelmann spruce beetle of ethylene dibromide emulsions applied to standing trees late in September 1950.

Ethylene Dibromide (Pounds per 5 Gallons)[1]	Replications of 4 Samples Each	Insects per Sq. Ft. of Bark		Per Cent Mortality
		Alive	Dead	
1	3	7.7	125.7	94.2
2	4	1.2	112.2	98.9
3	5	.8	66.8	98.8
1[2]	3	.7	47.4	98.5
Untreated	1	218.0	36.0	14.2

[1] All emulsions contained fuel oil and 80 per cent of water.
[2] Water-in-oil emulsion.

The fumigants, tested in emulsions and solutions, included commercial grades of dichloroethyl ether, ethylene dibromide, orthodichlorobenzene, paradichlorobenzene, trichlorobenzene chlorinated naphthalene, and lindane. They were dissolved in No. 1 fuel oil or in Stoddard solvent. Except where otherwise indicated all emulsions were oil in water.

The emulsifiable concentrates were prepared by mixing the fumigant, solvent, and emulsifier. They were clear solutions that were readily emulsified in water. Each gallon of the emulsifiable concentrate contained 8 ounces of a mixture of Triton X-100 (an alkylated arylpolyether alcohol) and Triton B-1956 (a modified phthalic glycerol alkyd resin). A blend of 3 parts of Triton X-100 and 5 parts of Triton B-1956 was used in concentrates containing No. 1 fuel oil, but equal weights were used in concentrates containing Stoddard solvent. However, only Triton B-1956 was used in the water-in-oil emulsion formulation. Zone oil, a parafin-base lubricating oil of 140 to 145 seconds Saybolt viscosity at 100°F. and with a flash point of 375°, was added to

some of the concentrates. The zone oil, emulsifier, and isopropyl alcohol were also added to some of the oil solutions.

The materials were applied to both standing infested trees and log sections cut from infested trees soon after they were felled. Applications to standing trees were made by means of a bucket pump. A 6-foot extension rod equipped with a No. 6 solid-stream nozzle aided in reaching the upper part of the infested stems. Approximately 3 gallons of material were applied to each tree, the exact amount depending on the size. The trees ranged from 12 to 36 inches diameter at breast height. They were treated until the insecticide began to run from the bark surface. Usually five trees were treated with each formulation to a height of 20 feet.

Log sections treated in the field were sprayed by means of a tank-type pressure sprayer equipped with a nozzle delivering a fine fan-shaped spray. Each section was treated until the insecticide started to run from the bark.

Log sections treated in the laboratory were sprayed with a tank-type pressure sprayer equipped with a pressure valve to regulate the rate at which the spray was applied. The nozzle used in the field tests was also used in the laboratory tests. The logs were rotated on a turntable during treatment, so that the insecticide was applied evenly over all portions.

The trees treated in the summer were sampled for insect survival three weeks later. The sampling methods varied. The trees treated in July of 1950 were sampled at breast height. The samples were 0.5 square foot in area on each of four exposures of the bole of each tree. Only the live insects were counted. If the mortality were sufficiently high (approximately 90 per cent) to warrant further examination, the treated trees were felled and samples taken on opposite sides of the bole at the base, 10, 15, and 18 feet. Survivals in untreated trees in the same area were compared with survivals in treated trees to determine the approximate mortality in the treated trees.

Trees treated during the fall of 1950 were sampled during the latter part of June 1951. Examination for mortality was delayed until then, because cold weather immediately following application made it difficult to determine the effect of the insecticides. High mortality caused by extremely low temperatures during the winter of 1950–51 precluded sampling above the basal 3 feet of the tree protected by the snow. Each of the treated trees was sampled on four exposures. These samples were 0.25 square foot in area.

Samples on log sections treated in the fall of 1950 were 0.5 square foot, and were taken from opposite sides of the log, whereas four samples taken on logs treated in the summer of 1951 were 0.25 square foot in area, and were taken on each of four exposures of each log.

RESULTS.—Tables 1, 2, 3, and 4 give the results with the emulsions. Ethylene dibromide was the only effective fumigant tested in the emulsions. Trichlorobenzene and chlorinated naphthalene were not effective at the dosages tested. The addition of zone oil in the emulsions did not increase their effectiveness. The results of

Table 3.—Effectiveness against the Engelmann spruce beetle of various fumigant emulsions applied in the laboratory to logs in December 1950. (4 replications of 3 samples each.)

FUMIGANT (POUNDS PER 5 GALLONS)[1]	INSECTS PER SQ. FT. OF BARK		PER CENT MORTALITY
	Alive	Dead	
Ethylene dibromide			
1	120.5	56.7	32.0
2	53.3	128.7	70.7
Chlorinated naphthalene			
1	160.7	54.2	25.2
2	204.0	23.8	10.4
4	161.5	39.0	19.5
Trichlorobenzene			
1	141.2	54.7	27.9
2	180.2	39.3	17.9
4	81.2	79.7	49.5
Untreated	263.5	15.3	5.5

[1] All emulsions contained fuel oil and 80 per cent of water.

Table 4.—Effectiveness against the Engelmann spruce beetle of ethylene dibromide emulsions applied in the field to logs in July 1951. (6 replications of 4 samples each.)

ETHYLENE DIBROMIDE (POUNDS PER 5 GALLONS)[1]	ADDITIVE	INSECTS PER SQ. FT. OF BARK		PER CENT MORTALITY
		Alive	Dead	
2	None	2.0	84.5	97.7
	Zone oil 1 pt.	3.7	90.5	96.1
	2 pt.	1.8	85.0	97.9
3	None	.8	110.2	99.3
	Zone oil 1 pt.	1.3	102.5	98.7
	2 pt.	2.5	59.7	96.0
Untreated	—	70.0	24.5	25.9

[1] All emulsions contained fuel oil and 80 per cent of water.

Table 5.—Effectiveness against the Engelmann spruce beetle of fuel-oil solutions of various fumigants applied to standing trees in July 1950.

Fumigant (Pounds per 5 Gallons)	Live Insects per Sq. Ft. of Bark at Indicated Height[1]					Relative Per Cent Survival at 5 Feet
	Base	Feet 5	10	15	18	
Ethylene dibromide						
0.75	0	2.7	18.5	15.2	31.2	0.19
1.5	0	0	1.4	2.7	.8	0
3	0	0	0	0	1.3	0
Paradichlorobenzene plus orthodichlorobenzene (1:1)						
8	1.3	3.8	6.3	.7	6.0	2.7
Orthodichlorobenzene						
8	0.5	3.0	1.2	9.0	11.0	2.1
Untreated	—	141.1	—	—	—	100

[1] Treated trees, 20 samples at 5-foot level and six samples at remaining levels, except eight samples at all levels for the 1.5 and 3 pounds of ethylene dibromide and 12 samples for orthodichlorobenzene at the 5-foot level; untreated trees, 28 samples.

the addition, however, are not conclusive because of the high mortality obtained with all applications in July 1951. Both Stoddard solvent and No. 1 fuel oil proved effective as solvents for the fumigants. No. 1 fuel oil, however, is more universally available and less costly.

The tests indicated that a minimum of 15 per cent of oil in the finished spray is necessary to obtain satisfactory mortality. When less oil was used, more fumigant was necessary to obtain comparable results. When greater amounts of oil were used, the effectiveness of the formulations was not increased sufficiently to justify the additional costs of materials and transportation. The maximum of 3 pounds of ethylene dibromide was required per 5 gallons of emulsion to obtain satisfactory kill.

Table 6.—Effectiveness against the Engelmann spruce beetle of fuel-oil solutions of various fumigants applied to standing trees late in September 1950.

Fumigant (Pounds per 5 Gallons)	Replications of 4 Samples Each	Insects per Sq. Ft. of Bark		Per Cent Mortality
		Alive	Dead	
Dichloroethyl ether				
4	2	0	94.0	100
Orthodichlorobenzene				
4	5	21.2	233.2	91.7
4[1]	5	4.6	114.0	96.1
8	5	12.8	201.6	94.0
Ethylene dibromide				
0.75	5	4.0	192.6	98.0
1.5	5	0.2	173.2	99.9
Untreated	1	218.0	36.0	14.2

[1] Plus emulsifier 0.25 pound.

Further testing is needed to determine whether there is a significant difference in the effectiveness of the 2- and 3-pound dosages. Meanwhile, it is recommended that the 3-pound dosage be used.

Tables 5, 6, 7, and 8 give the results with the oil solutions. Ethylene dibromide again was the most effective fumigant tested. Dichloroethyl ether, orthodichlorobenzene, and a mixture of orthodichlorobenzene and paradichlorobenzene were also effective at the dosages tested. However, more than twice as much of these last materials was needed to obtain comparable results. Tests with dichloroethyl ether were not continued, because the major objective of the study was to develop an emulsion spray. In laboratory

Table 7.—Effectiveness against the Engelmann spruce beetle of fuel-oil solutions of fumigants applied in the laboratory to logs in December 1950. (4 replications of 3 samples each.)

Fumigant (Pounds per 5 Gallons)	Insects per Sq. Ft. of Bark		Per Cent Mortality
	Alive	Dead	
Orthodichlorobenzene			
4	27.0	189.2	87.5
4[1]	41.3	154.3	78.9
8	13.5	252.5	94.9
Ethylene dibromide			
0.5	33.7	115.3	77.4
0.5[1]	4.3	154.5	97.3
1	17.0	85.5	83.4
1[1]	0.5	188.7	99.7
1.5	4.8	159.5	97.1
Trichlorobenzene			
1	81.5	101.7	55.5
2	27.6	156.3	85.0
4	39.5	176.0	81.7
Chlorinated naphthalene			
0.5	80.2	109.2	57.7
1	68.3	93.7	57.8
2	92.5	126.5	57.8
Emulsifier only	181.7	64.2	26.1

[1] Plus emulsifier 0.25 pound.

Table 8.—Effectiveness against the Engelmann spruce beetle of fuel-oil solutions of various fumigants applied in the field to logs in July 1951. (6 replications of 4 samples each.)

FUMIGANT (POUNDS PER 5 GALLONS)	ADDITIVE	INSECTS PER SQ. FT. OF BARK		PER CENT MORTALITY
		Alive	Dead	
Orthodichlorobenzene				
8	None	1.7	94.0	98.2
	Isopropyl alcohol 1 qt.	3.7	98.0	96.4
	Emulsifier 0.25 lb.	5.7	110.8	95.1
Ethylene dibromide				
1	None	0.2	97.0	99.8
	Isopropyl alcohol 1 qt.	0	80.3	100
	Emulsifier 0.25 lb.	0	125.5	100
	Zone oil 1 qt.	0	69.5	100
	2 qt.	0.2	95.2	99.8
1.5	None	0	80.8	100
	Isopropyl alcohol 1 qt.	0	76.8	100
	Emulsifier 0.25 lb.	0	59.7	100
	Zone oil 1 qt.	0	103.3	100
	2 qt.	0	88.5	100
Lindane 0.1	None	7.0	60.3	89.6
Untreated	—	70.0	24.5	25.9

tests (Table 7) the effectiveness of ethylene dibromide solutions was increased by the addition of Triton B-1956 emulsifier. However, in field tests increased effectiveness due to the addition of the emulsifier isopropyl alcohol, or zone oil was not demonstrated because of the high mortality obtained in all applications.

Satisfactory control of broods of the Engelmann spruce beetle was obtained with a blend of 1.5 pounds of ethylene dibromide and sufficient No. 1 fuel oil to make 5 gallons of solution. Good results were obtained with half of this concentration. Further research is needed to determine the effect of additives and the minimum ethylene dibromide requirements.

As indicated in the tables, 1.5 pounds of ethylene dibromide in oil solutions is as effective as 3 pounds of the fumigant in an emulsion. However, increased cost of the additional fumigant required in the emulsion is more than offset by the larger proportion of oil in the solution, and the higher transportation costs.

The emulsion containing 3 pounds of ethylene dibromide in 5 gallons of spray was used extensively by the U. S. Forest Service on the Engelmann spruce beetle control project in Colorado during August 1952. The results were equal to those obtained with the orthodichlorobenzene-fuel oil solution, the material used to treat nearly a million trees during the preceding three seasons. The workmen much preferred to use the emulsion of the ethylene dibromide because it was less disagreeable. The situation did not permit any comparison of the operational costs of the two materials.

Control of the European Chafer on Deciduous Nursery Stock *in situ*[1]

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The occurrence of the European chafer, *Amphimallon majalis* (Raz.), in certain nursery-growing sections of New York has necessitated the development of control measures to prevent the dissemination of this pest to noninfested areas. The control of grubs in the soil around perennial plants and small balled and burlapped evergreen stock is accomplished by the application of DDT at a minimum rate of 25 pounds per acre to the entire block. However, the movement of large deciduous trees, with trunk diameters of 4 to 6 inches and heights of 20 to 30 feet, is practiced to some extent. Since trees of this size with a soil ball weigh several tons, the use of a plant dip is not very practical. Therefore, a surface application of a fumigant offered definite possibilities.

Gambrell & Mason (1948) reported that 10 ml. of an ethylene dichloride-ethylene dibromide mixture per gallon of water per square yard of soil surface gave 82.9 to 100 per cent control of third-instar European chafer grubs 3 weeks after application.

Preliminary work by the authors in 1950 with the ethylene dibromide-chlordane mixture known as U. S. mixture 253 as a surface application indicated that the material was ineffective against the prepupae and pupae of this insect. On the other hand, Mason & Chisholm (1949) reported that the same material used at the rate of 30 ml. in 4 to 8 quarts of water per square yard was very effective against the pupae of Japanese beetles, and that 5 or 10 ml. of the mixture in 8 quarts of water gave 100 per cent mortality of third-instar grubs in 2 to 3 weeks. It was therefore believed that the mixture would give reasonable assurance of eliminating European chafer grubs in the soil.

Representatives of the New York State Department of Agriculture and Markets, New York State Agricultural Experiment Stations, and the U. S. Bureau of Entomology and Plant Quarantine met in August 1951 and decided on a tentative emergency treatment. It was to be made, under the supervision of a state inspector, to all deciduous trees *in situ* that were to be moved with a ball of soil from the untreated blocks in the infested nurseries, with the understanding that the requirements might be modified as further information was developed by research. The tentative schedule of treatment was as follows:

1. Seasonal limitations: Between September 1 and May 10.
2. Material: U. S. mixture 253, containing 13.0 per cent of ethylene dibromide; 6.5 per cent each of chlordane, Cellosolve, and Tween-20; and 67.5 per cent of isopropyl alcohol (all percentages by weight).
3. Concentration and application: 40 ml. per gallon per square yard of soil surface.
4. Soil temperature: 50° F. or higher at 2-inch depth.
5. Preparation of tree: Removal of soil to a depth of at least 3 inches over an area 3 feet wider than the proposed soil ball, and leveling to avoid run-off of fumigant.
6. Holding period: Treated area about tree left undisturbed for 5 days; ball removable after this period, but not later than June 1.

The soil should be friable, and not excessively wet or dry, and the treatment should not be made during periods of moderate to high winds. The seasonal limitations were imposed so that fumigation would be aimed at only the larval stage. Removal of soil to a depth of 3 inches around the trees would, under most conditions, eliminate most of the grubs present.

A treatment such as that mentioned above is highly desirable because of the quick action of ethylene dibromide as a fumigant and the residual action of chlordane. The dosage of 40 ml. per gallon per square yard is equivalent to an application of 25.5 pounds of chlordane per acre.

Further research was undertaken during the fall of 1951 to obtain information on the effectiveness of this tentative schedule. In the light of results obtained, the work was continued with some modi-

[1] Journal Paper No. 910, New York State Agricultural Experiment Station (Geneva), October 31, 1952.

[2] The authors acknowledge the assistance of V. Hopkins, W. Cass, and P. Gregory in all phases of this work.

Table 1.—Control of third-instar European chafer grubs with ethylene dibromide-chlordane mixture, 5-day exposure period. Dosage 40 ml. per square yard. Newark, N. Y. 1951.

Date Treated	Mean Soil Temperature at 2-Inch Depth, °F.	Mean Number of Grubs Recovered per Tree		Per Cent Control			
		Treated	Check	At Digging	After 3 Days	After 1 Week	After 2 Weeks
Sept. 23–24	—	0	42	100	—	—	—
19–20	66	0	44	100	—	—	—
Oct. 3– 4	57	0	38	100	—	—	—
Sept. 26–27	53	<1	37	99	100	—	—
Oct. 17–18	53	3	38	92	99	100	—
10–11	46	9	50	82	100	—	—
24–25	42	13	48	73	87	89	96

fications during the spring and fall of 1952.

TESTS IN FALL SEASONS OF 1951 AND 1952.—In the fall tests the soil was removed from an area 4 feet square around the base of each tree. Fifty third-instar grubs were placed on the surface of the soil 1 or 2 days before fumigation and allowed to burrow into the ground.

During the fall of 1951, five such trees were prepared each week, two trees to be treated on each of 2 days and the fifth tree for use as a check. The fumigant was applied to the surface of the ground with a sprinkling can at the rate of 40 ml. per gallon per square yard; the check trees received an equivalent amount of water. Five days later the area in which the grubs had been introduced was dug and carefully examined for recovery of grubs. All live grubs found were placed in insecticide-free soil, held at room temperature, and examined for mortality 3 days, 1 week, and 2 weeks after digging. The work was conducted from early September until the last week of October.

During the fall of 1952, two trees from each group of five were treated 2 days after grubs had been introduced at the rate of 20 ml. and two at 40 ml. per gallon per square yard, and the fifth tree was left untreated as a check. In addition to this treatment, some groups of trees were fumigated 1 week after grubs had been introduced to determine whether lengthening the interval before fumigation would reduce the effectiveness of the fumigant. The exposure period between fumigation and digging was 5 days in all groups. This interval allowed the soil to become more compact on the surface, especially if there was an intervening rain, and also allowed the grubs to penetrate deeper. The work in 1952 was conducted during October and November.

The results shown in tables 1 and 2 indicate that treatment with ethylene dibromide-chlordane was effective in eliminating the grubs when the mean soil temperature was above 45° F. Complete kill was obtained with a 40-ml. dosage on three groups of trees at time of digging, and in all treatments within 2 weeks after digging with the temperature above 45°. At 42° the treatment became ineffective, and healthy grubs were present after the 2-week holding period.

There was little difference between the 20- and the 40-ml. dosages during the fall of 1952, but the grubs exposed to the higher dosage showed a little higher mortality when held in insecticide-free soil. Trees fumigated 7 days after being infested showed no significant difference from those treated 2 days after being infested at comparable soil temperatures.

TESTS IN SPRING OF 1952.—*Treatment of Larvae.*—The techniques were in general the same as those of the preceding fall, but with some modifications. The grubs were introduced 1 week before the application of the fumigant, dosage levels over a greater range were tested, and the fumigation period prior to digging was increased in some groups of trees.

One series of tests was made after a 5-day exposure period and another after 10 days. For the 5-day exposure period the weekly schedule consisted in treating two trees each with 40-ml. and 80-ml. dosages. As soon as the 80-ml. dosage began giving nearly complete kill at time of digging, the dosage levels were decreased to 20 and 40 ml. per square yard. Other groups of trees were left undisturbed for 10 days before digging. All living grubs

Table 2.—Control of third-instar European chafer grubs with ethylene dibromide-chlordane mixture 5-day exposure period. Newark, N. Y. 1952.

Date Treated	Mean Soil Temperature at 2-Inch Depth, ° F.	Dosage, Ml. per Square Yard	Mean Number of Grubs Recovered per Tree		Per Cent Control			
			Treated	Check	At Digging	After 3 Days	After 1 Week	After 2 Weeks
Fumigated 2 days after infesting								
Oct. 16	45	20	9	35	74	98	100	—
		40	13	35	61	100	—	—
24	45	20	11	25	58	97	96	96
		40	21	25	18	100	—	—
29	44	20	22	22	0	94	100	—
		40	21	22	2	94	100	—
Nov. 2	43	20	7	33	77	96	96	—
		40	4	33	88	100	—	—
14	42	20	25	41	40	95	97	100
		40	21	41	48	97	97	97
5	40	20	17	30	42	79	94	100
		40	13	30	55	83	94	95
12	39	20	23	39	41	89	89	94
		40	18	39	53	93	97	97
7	38	20	29	46	36	89	91	94
		40	23	46	50	100	—	—
Fumigated 7 days after infesting								
Oct. 2	52	20	8	41	81	96	100	—
		40	5	41	89	98	100	—
22	45	20	19	44	57	99	100	—
		40	13	44	71	100	—	—
24	45	20	19	38	52	100	—	—
		40	14	38	63	96	96	100
Nov. 7	38	20	17	22	15	96	100	—
		40	29	22	0	100	—	—

were similarly held in the laboratory in insecticide-free soil and checked for mortality 3 days, 1 week, and 2 weeks after digging.

The temperature was below 50° F. for only the group of trees treated on the first date. Complete kill at time of digging was obtained in only one test. The data are summarized in table 3.

Control with the 5-day exposure period was generally less effective in the spring than in the fall. The reason for this difference is not known, but it may be related to the age of the grubs, the length of time the grubs were in the soil before fumigation, and the soil moisture in the spring. No normal grubs were recovered from trees receiving the 40-ml. dosage after May 8, but the 20-ml. dosage proved inadequate, and apparently normal grubs were generally present even after the 2-week holding period.

In the 10-day exposure constant rates of 10 and 20 ml. per gallon per square yard were used. The 10-ml. dosage proved inadequate, for normal grubs were recovered from nearly all trees fumigated at this rate. Many of them remained normal for the entire 2-week holding period. The 20-ml. dosage gave results comparable to those given by the 40-ml. dosage at the 5-day exposure period. Only one normal grub was recovered with 20-ml., and this one grub became moribund by the end of the 2-week holding period.

Treatment of Prepupae and Pupae.—The work was continued in June 1952 to determine the effects of the treatment on

Table 3.—Control of third-instar grubs with the ethylene dibromide-chlordane mixture. Spring 1952, Newark, N. Y.

Date Treated	Mean Soil Temperature, at 2-Inch Depth, °F.	Dosage, Ml. per Square Yard	Mean Number of Grubs Recovered per Tree		Per Cent Control			
			Treated	Check	At Digging	After 3 days	After 1 week	After 2 weeks
			5-day exposure period					
Apr. 10	43	40	43	46	7	91	95	100
		80	35	46	25	95	97	98
17	55	40	6	25	76	90	92	96
		80	2	25	92	100	—	—
24	54	40	6	37	84	97	97	98
		80	5	37	87	96	100	—
May 1	52	40	7	45	85	98	100	—
		80	1	45	99	99	100	—
8	53	20	3	35	90	—	98	98
		40	0	35	100	—	—	—
16	53	20	6	24	75	85	88	86
		40	4	24	83	94	94	100
29	60	20	7	33	79	95	100	—
		40	1	33	95	98	100	—
			10-day exposure period					
Apr. 21	54	10	25	39	35	50	59	65
		20	3	39	94	99	99	98
28	53	10	17	35	50	77	90	92
		20	5	35	86	95	97	98
May 5	52	10	19	20	5	28	69	83
		20	1	20	97	100	—	—
29	63	10	6	37	84	82	—	—
		20	1	37	99	100	—	—

Table 4.—Control of prepupae and pupae with ethylene dibromide-chlordane mixture, 5-day exposure period. Newark, N. Y. 1952.

Date Treated	Mean Soil Temperature at 2-Inch Depth, °F.	Predominant Stage When Fumigated	Dosage, Ml. per Square Yard	Mean Number of Grubs Recovered per Tree		Per Cent Control
				Treated	Check	
June 6	67	Creamy grubs	20	15	40	64
			40	7	40	83
11	68	Prepupae	20	19	38	51
			40	23	38	41
13	71	Prepupae	20	16	30	47
			40	27	30	12
25	75	Pupae	20	27	39	9
			40	36	39	25
27	73	Pupae	20	20	8	0
			40	24	8	0

the prepupal and pupal stages of the chafer. For this work only the 5-day exposure period and the 20- and 40-ml. dosages were tested. The trees were prepared as usual, and third-instar grubs were introduced. The date at which to fumigate was determined by checking the development of grubs around another check tree. The results shown in table 4 indicate inadequate control when grubs were in the "creamy" and prepupal stages, and practically no control of the pupae. "Creamy" refers to the developmental stage of a grub just preceding the prepupal stage, when the grub has stopped feeding, has turned very flaccid, and has become creamy in color.

The 40-ml. dosage gave no better control than did the 20-ml. dosage. There was some indication of effect of the fumigant on the prepupae in one instance, manifesting itself in retarded development. All the healthy individuals recovered in the soil of the trees treated on June 13 were prepupae, but those dug from the check tree were predominantly pupae. No attempt was made to hold prepupae and pupae in the laboratory, since these stages are easily injured in digging. The lateness of these stages in the soil was not natural, but was due to the grubs having been held in cold storage.

Observations for phytotoxic symptoms were made on fumigated trees in both fall and spring, but none could be found at any of the dosages used.

SUMMARY.—In the control of the European chafer, *Amphimallon majalis* (Raz.), a need has developed for a surface fumigation treatment where large trees are removed with a ball of soil from untreated nursery plantings. In the fall of 1951 the use of an ethylene dibromide-chlordane mixture, known as U. S. mixture 253, at the rate of 40 ml. per gallon of water per square yard gave 100 per cent control of third-instar grubs at the end of a 5-day exposure in several groups of trees at the time of digging and in all treatments 1 week after digging when the temperature was above 50° F. In the fall of 1952 nearly as good control was obtained with 20 ml. as with 40 ml. per gallon per square yard.

In the spring of 1952 the results were less promising, complete kill of grubs being obtained in only one group of trees treated with a 40-ml. dosage. A 10-ml. dosage with a 10-day exposure period proved inadequate for control of grubs. The results with 20 ml. for a 10-day exposure period were comparable to those with 40 ml. for the 5-day exposure period. Prepupae and pupae were not controlled by the use of this treatment. No phytotoxic symptoms were visible on any of the trees.

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Insecticide Tests for Control of Maggots in Turnips[1]

Loyd L. Stitt[2,3,4]

Maggots, mainly *Hylemya brassicae* (Bouché), have consistently caused very severe injury to turnips in western Washington. Very satisfactory control of *H. brassicae* has been obtained on cabbage, cauliflower and radishes. The same materials and methods of application have not given desired control of maggots on turnips. Work during the past 2 years indicated that great differences in degree of maggot control were obtained with different insecticide treatments and different methods of application.

Oughton (1951) reported that for more than 50 years entomologists have studied maggots that infest cruciferous crops. Control measures beneficial to growers of radishes, cabbages and cauliflower have resulted, but nothing of much use on turnips (rutabagas) has been found. Stitt (1951), testing effectiveness of insecticides for maggot control in radishes, found furrow or trench treatment superior to broadcast or surface treatment.

Materials and Methods.—Purple-top White Globe turnip seed was used in these experiments. Plots, consisting of single rows ten feet long, were planted 16 inches apart in beds of four rows with two feet between beds. Randomized block design was used in all experiments. In 1951 all insecticides were applied in the furrow with the seed. Furrow and surface applications of insecticides were used in the 1952 experiments. The experiments were started at different periods during the growing season so that the differences in seasonal conditions and their effects on maggot control could be investigated. Planting dates for the assigned experiment numbers were: *1951:* 51-19, June 1; 51-25, June 15; 51-26, June 18; and *1952:* 52-7, April 15; 52-22, June 21; 52-31, September 4.

All turnip seed was planted with a drill seeder.[5] The covering shoes and packer wheel were removed from the seeder during planting. With shoes and wheel removed, the opening plow left a small open furrow with most of the seed exposed after the planting operation. Insecticidal treatments were applied after the seed were planted. Dusts were applied by placing a volume unit of insecticide in a salt shaker and shaking it into the furrow. Liquid treatments at known volumes were sprinkled in the furrow. A 300 to 400 ml. capacity bottle with clothes-sprinkler cap-equipped mouth was used for application of liquid insecticides. The holes in clothes-sprinkler cap were enlarged to 0.0625-inch size. Very uniform distribution of the insecticidal material, either in dust or liquid form, was obtained with the above equipment.

Seed and insecticide were covered with soil by using a double-wheel hoe equipped with the covering shoes and packer wheel from the drill seeder. This type of equipment prevented contaminating or mixing the insecticides between plots.

Insecticides used, concentrations, and amounts of material per 1000 lineal feet of row are presented in table 1. A thousand lineal feet of row would be approximately 0.034 acre, as computed from the row spacing used.

Field Data.—Data on the efficacy of insecticidal treatments in the control of maggots on turnips usually were taken when the turnips were two to three inches in diameter. Amount of maggot injury to the turnips was a better criterion of insecticide performance than were larval counts. In many cases larval development or activity was not synchronized with the period when data were taken. Amount of injury, regardless of time, could be determined when the turnips were examined. A classification of maggot injury was established. Injury rating categories were: clean, 0; slight, 1; moderate, 2; and severe, 4. Clean turnips were those in which no signs of feeding could be detected. Slight injury was where superficial feeding was found on the surface, but in

[1] Scientific Paper No. 1178, Washington Agricultural Experiment Stations, Pullman. Project No. 665.

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[3] Grateful acknowledgement is made to Edward C. Trivette and Robert W. Zwick for assistance in carrying out these studies. Also, we acknowledge the exchange of ideas and assistance of Dr. K. W. King and assistants of the Field Crop Insect Section, Science Service, Canada Agriculture, Victoria, British Columbia. Photograph, Figure 1, courtesy of Charles H. Starker, Pacific Supply Cooperative, Portland, Oregon.

[4] These investigations were partially supported by research grants from Velsicol Corporation, Chicago, Illinois, and Shell Chemical Corporation, Julius Hyman & Company Division, Denver, Colorado.

[5] Planet Junior drill seeder.

Table 1.—Effectiveness of insecticides at different amounts and with different application methods against maggots injuring turnips. Puyallup, Wash. 1951–1952.

Treatments	Amount per 1000 Lineal Feet of Row or Equivalent Area		Mean Injury Rating by Treatments and Experiments					
			Furrow Treatment[1]					Broadcast Treatment[2]
	Dust	Active Ingredient	51–19	51–25	51–26	52–7	52–31	52–22
Dust (Per Cent)	*Pounds*	*Pound*						
Aldrin 2.5	1.43	0.036	13.2		11.2			
Aldrin 2.5	4.30	0.108		12.4				
Aldrin 2.5	1.16	0. 29				8.8		
Aldrin 2.5	0.58	0.015					21.4	
Aldrin 2.5	2.01	0.050					18.4	
Aldrin 2.5	3.44	0.086						20.4
Aldrin 2.5	17.22	0.430						=2.0
BHC 1% gamma	4.65	0.046		33.2				
Calomel 3.39 Hg	2.05	0.695				70.6		
Calomel 3.39 Hg.	2.04	0.692					61.8	
Chlordane 5.0	1.57	0.078	34.3		29.8			
Chlordane 5.0	4.70	0.235		30.4				
Chlordane 5.0	1.86	0.093					22.4	
Chlordane 5.0	3.44	0.172						46.4
Chlordane 5.0	17.22	0.861						16.4
Dieldrin 2.5	1.36	0.034	38.5		41.6			
Dieldrin 1.5	0.79	0.012				23.6		
Heptachlor 2.5	1.31	0.033	9.2		5.4			
Heptachlor 2.5	1.12	0.028				8.2		
Heptachlor 2.5	0.56	0.014					16.2	
Heptachlor 2.5	1.85	0.046					14.2	
Heptachlor 2.5	3.44	0.086						13.4
Heptachlor 2.5	17.22	0.430						8.0
Isodrin 1.0	1.29	0.013				23.6		
Isodrin 2.0	1.40	0.028					25.0	
Isodrin 2.0	3.44	0.069						23.0
Isodrin 2.0	17.22	0.344						11.6
Lindane 1.0	4.28	0.043		38.2				
Lindane 1.0	3.44	0.034						50.6
Lindane 1.0	17.22	0.172						27.4
Malathon 5.0	1.47	0.074	79.0		75.4			
Malathon 5.0	4.42	0.221		80.0				
Malathon 5.0	1.23	0.062				67.0		
Q-137[3] 5.0	1.04	0.052	80.0		76.2			
Q-137 5.0	3.10	0.155		78.8				
Liquid	*Gallons*							
Carco-X[4] 1–200	6.89	0.034[5]	78.3	79.0	76.0			
Endrin 18.5 Emul. 1–800	3.44	0.0069				34.6		
Untreated Check	—	—	79.0	77.0	74.2	74.4	73.6	48.6
Maximum Mean Rating	—	—	80.0	80.0	80.0	80.0	80.0	80.0
S.E. of Mean			2.79	5.05	2.81	2.49	3.23	4.03
Significant Difference			8.01	14.85	8.14	7.21	9.36	11.52

[1] Furrow treatment—Insecticide applied to seed in seed furrow.
[2] Broadcast or surface application. Raked so that some toxicant 0.25 inch in soil. Amounts active ingredient for Exp. 52-22 figured on portion of acre equivalent to 1000 lineal feet of row, based on row spacings in other experiments.
[3] Q-137—1,1 bis(p-ethyl phenyl)2,2 dichloroethane. Rohm & Haas Co.
[4] Carco-X—65.0% Creosote oil, gamma isomer BHC 0.5%, other isomers BHC 1.5%, Inert ingredients 33.0%. Getzum Products.
[5] Amount of concentrate in portion of one gallon.

no case had feeding penetrated into the flesh. Slight injury would not reduce the marketing grade. Moderate injury consisted of maggot feeding which had penetrated the skin and was in the flesh, but not over a large area or to considerable depth. Severe injury was a total loss as far as food was concerned. Figure 1 shows the injury rating categories.

Twenty turnips were selected at random from each plot and examined for injury. Each turnip was placed in its injury rating category. The number of turnips in each category multiplied by the numerical value for each rating gave the injury rating per plot. The maximum injury rating was 80 when all turnips examined were severely damaged. Data for each treatment and each experiment, on the basis of mean injury rating, are summarized and presented in table 1. Analysis of variance was used in all experiments.

RESULTS.—Aldrin and heptachlor consistently gave very satisfactory control. Very few turnips were damaged to the extent that the commercial grade was reduced. Less injury occurred in the heptachlor treatments than in the aldrin treatments, but this reduced injury was not significant according to the analytical data.

Injury was significantly reduced in plots treated with chlordane, dieldrin, endrin and isodrin when compared with untreated check plots. These treatments were inferior to aldrin and heptachlor treatments.

Materials unsatisfactory in the control of maggots, as tested, were: BHC 1% gamma; calomel-gypsum 3.39 per cent Hg.; *Carco-X;* lindane; malathon; and Q-137.

Furrow application of insecticides resulted in better maggot control than broadcast application on the basis of equivalent amounts of active ingredient of insecticides per 1000 lineal feet of row. Furrow application was used in experiments 51-19, 51-25, 51-26, 52-7 and 52-31, whereas broadcast application was used in 52-22. Considerably lower amounts were used in furrow treatment than in broadcast treatment. Maggot control, in general, was better in the furrow treatment (Table 1).

Planting date for experiment 52-31 was September 4, the latest during the two years of investigations. Control was not as satisfactory, even at higher dosages, as that obtained when plantings were made in April or June.

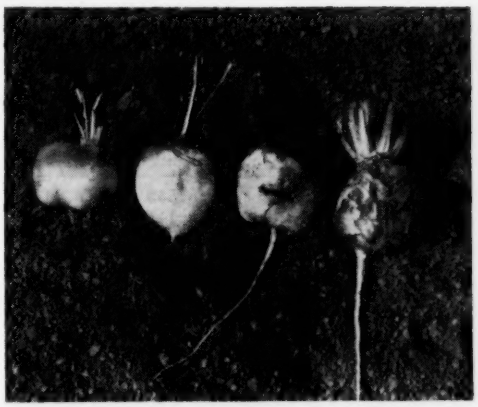

FIG. 1.—Injury rating categories for turnips. (L-R) Clean 0; Slight 1; Moderate 2; Severe 4.

MAGGOT DETERMINATIONS.—Larvae causing injury to turnips were mainly *Hylemya brassicae* (Bouché), but *H. cilicrura* (Rond.), *H. fugax* (Mg.) and *Muscina* species were also found. Ronald Forbes, Field Crop Insect Section, Science Service, Canada Agriculture, Victoria, British Columbia, made three determinations of larvae in 1952. Larvae collected from turnips in July were: *H. brassicae* 8; *H. cilicrura* 3; and *Muscina* species 2. Sixty-one larvae collected on October 25 were all *H. brassicae.* Larvae were feeding on turnips the latter part of November. Larvae collected on November 19 were: *H. brassicae* 140, and *H. fugax* (Mg.) 2.

RESIDUE ANALYSES.—Samples of turnips for residue studies were taken from the 1952 aldrin, chlordane, and heptachlor plots. Aldrin residue analyses were made by W. E. Westlake, Bureau of Entomology & Plant Quarantine, Insecticide Investigations. Bioassay investigations for heptachlor were made by the Boyce Thompson Institute. The modified Polen-Silverman method of analysis was used for heptachlor. Chlordane was analyzed by the modified Davidow method. Analyses for chlordane and heptachlor were made by the Velsicol Corporation. In all analyses the whole turnip was used after being washed and brushed. Data of residues as found in turnips from plots treated with aldrin, chlordane, heptachlor and untreated checks are presented in table 2.

FLAVOR-PHYTOTOXICITY STUDIES.—

Table 2.—Analyses of turnips for insecticidal residues.

TREATMENT	ACTIVE INGREDIENT /ACRE (LBS.)	P.P.M.	P.P.M. CORRECTED WITH CHECK
Aldrin	0.84	0.553	0.412
Check	—	0.141	—
Aldrin	0.84	0.511	0.253
Check	—	0.258	—
Aldrin	0.84	0.605	0.439
Check	—	0.166	—
Aldrin	0.84	0.571	0.231
Check	—	0.340	—
Aldrin	0.84	0.620	0.301
Check	—	0.319	—
Chlordane	5.00	0.037	0.000
Check	—	0.038	—
Heptachlor	0.81	0.018	0.000
Heptachlor	0.81	0.015	0.000
Check	—	0.016	—
Check	—	0.029	—
Check	—	0.020[1]	—
Heptachlor	2.50	0.042	0.022
Check	—	0.020	—
Heptachlor	12.5	0.098	0.078
Check	—	0.020	—

[1] Bioassay.

Some insecticides have caused plant injury and others have caused off-flavor. An experiment was planned in which normal and excessive amounts of five insecticides were applied as dusts to the soil. Materials used were aldrin 2.5 per cent; chlordane 5.0 per cent; heptachlor 2.5 per cent; isodrin 2.0 per cent; and lindane 1.0 per cent. These dusts were applied at 100 and 500 pounds per acre. All insecticides were applied to the soil surface and raked lightly so that some of the toxicant was worked into the soil to the depth of 0.25 inch. No phytotoxic action to the turnip plant was observed. Observations were made at emergence, seedling stage, and during the balance of the growing period.

Off-flavor has been reported in various vegetables due to certain insecticide treatments. Turnips grown in plots treated with insecticides used in flavor-phytotoxicity studies were sampled for differences such as off-flavor and quality. The method used for taste sampling was that suggested by Dr. Edward Ross, Food Processing Laboratory, State College of Washington.

Samples were taken from treated and untreated plots and prepared for presentation to a taste panel composed of station personnel. Each taster was presented with a set of five samples comprising either three treated and two untreated, or two treated and three untreated sample portions. A set was presented in a random order and the panel member was instructed to taste each one and classify as treated or untreated. The probability of getting a correct separation due to chance alone is one-tenth, Lockhart (1951).

Usually six sets were used in assessing a treatment. Additional sets were used when the correct separations definitely indicated differences in the first sampling. Of the treatments subjected to taste tests, only heptachlor at 12.5 pounds actual per acre was rechecked.

In the isodrin treatments there was one correct separation in each dosage level. This was above the probability of chance, but none of the tasters making correct separations reported any definite differences. For the lindane treatments there was one correct separation at the low dosage, and two at the high dosage. Differences were not definite.

In the high dosage treatment of heptachlor (12.5 pounds per acre) the tasters definitely discriminated between the untreated and treated samples. In the first set three out of six, and on a recheck four out of six, made correct separations. In the case of heptachlor treatments it was not the detection of objectionable flavors, but rather that the heptachlor samples were less fibrous and more crisp than the untreated check samples. Maggot injury often caused the turnips to be woody and fibrous in texture.

SUMMARY.—Aldrin and heptachlor dusts, applied in the furrow with the seed at 0.03 to 0.1 pound active ingredient per 1000 lineal feet of row, usually gave satisfactory control of maggots injuring turnips. Broadcast or surface application was less effective than furrow treatment when equivalent amounts per crop acre were used. Residues in p.p.m. corrected with the check ranged from 0.231–0.439 for aldrin and 0.000–0.078 for heptachlor. There was no indication of off-flavor in turnips treated at rates which gave satisfactory control of maggots. BHC 1 per cent gamma, calomel-gypsum 3.39 per cent Hg., *Carco-X*, lindane 1 per cent, malathon 5 per cent, and Q-137 5 per cent gave unsatisfactory control in these tests. Chlordane, dieldrin, endrin and isodrin gave inferior control compared with aldrin or heptachlor treatments.

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Baits for the Control of Resistant Flies[1,2]

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House flies, *Musca domestica* L., infesting dairies near Orlando, Fla., had developed such a high resistance to all the chlorinated hydrocarbon insecticides by 1951 that none of these materials gave satisfactory control as either residual or space sprays. It was evident, therefore, that new methods and materials were needed to reestablish good fly control in this area.

In the fall of 1951 an investigation was started to determine the possibilities of using insecticidal baits for the control of house flies. Of a large number of materials tested as potential attractants, brewers' malt and blackstrap molasses proved to be the most satisfactory. Water solutions of these materials were combined with various insecticides to compare the relative toxicities of the formulations. Subsequently the most promising mixtures were tested against natural house fly populations. The results obtained thus far in the laboratory and field phases of this study are presented here as information on the status of the research and not as recommendations for use.

LABORATORY TOXICANT STUDIES.—Laboratory evaluations were made with 11 inorganic and 4 organic compounds as bait toxicants against adult house flies. Comparative tests were run with the toxicants dissolved in water and in a 5 per cent water solution of malt. The chemicals were tested at various concentrations.

The solutions were applied in 1-ml. quantities to 1-inch-square cotton pads,

Table 1.—Effectiveness of various toxicants in water and malt-water solutions against house flies. (Average of 2 replications of 2 cages with 25 female flies in each.)

		Without Malt		With Malt	
Toxicant	Per Cent Concentration	Per Cent Knockdown in 24 Hours	Per Cent Kill in 48 Hours	Per Cent Knockdown in 24 Hours	Per Cent Kill in 48 Hours
TEPP	0.001	27	27	13	13
	0.05	89	90	88	80
	0.1	93	93	96	96
	0.2	78	78	100	100
	0.25	76	80	98	98
	0.5	80	88	98	98
	1.0	52	52	93	95
	2.0	37	42	88	92
	5.0	17	22	92	76
Sodium fluoroacetate	0.1	36	36	20	44
	0.25	92	90	90	96
	1.0	98	96	100	100
	2.0	98	98	92	100
Sodium arsenate	0.001	4	6	2	2
	0.05	14	12	4	4
	0.1	22	20	34	36
	0.2	79	81	78	80
	0.25	82	82	88	88
	0.5	100	100	100	96
	1.0	100	100	98	98
	2.0	100	100	100	100
	5.0	96	94	100	100
Sodium arsenite	0.25	88	86	4	56
	0.5	92	92	70	84
	1.0	88	94	98	100
	2.0	88	90	100	100
	5.0	54	56	100	100
Sodium fluosilicate	0.25	6	8	12	20
	0.5	10	16	12	20
	1.0	90	90	42	68
	2.0	96	96	52	84
	5.0	82	82	62	82
Ammonium bifluoride	0.25	34	18	12	56
	0.5	30	26	42	84
	1.0	70	48	78	100
	2.0	36	38	68	98
	5.0	8	8	68	100
Sodium fluoride	0.25	36	38	0	10
	0.5	30	38	8	66
	1.0	40	48	14	66
	2.0	24	28	34	98
	5.0	6	9	62	100
Formaldehyde	5.0	34	42	34	42
Nicotine sulfate	5.0	35	40	7	15
Cobaltous chloride	5.0	2	2	0	44
Chloral hydrate	5.0	6	8	22	36
Chromium potassium sulfate	5.0	6	8	4	20
Copper sulfate	5.0	12	12	2	4
Hydrochloric acid	5.0	2	8	24	26
Sodium hydroxide	5.0	2	4	6	10

[1] Presented at the meeting of the Association of Economic Entomologists at Philadelphia, Pa., December 15–18, 1952.

[2] This work was conducted at the Orlando, Fla., laboratory of the Bureau of Entomology and Plant Quarantine under funds allotted to the Bureau by the Department of the Army.

[3] The writers wish to thank W. C. McDuffie and C. V. Bowen, of the Orlando laboratory, for their advice and assistance; also A. A. Whipp, of the California Spray-Chemical Corporation, who furnished the TEPP used in these studies and suggested the tests conducted with the sprinkling can.

Table 2.—Toxicity to house flies of freshly prepared and aged baits containing TEPP in malt and molasses. (Average of 2 tests of 20 female flies each.)

Age of Bait	Per Cent Concentration	Per Cent Mortality After Indicated Exposure Period					
		Malt Baits			Molasses Baits		
		1 Hour	2 Hours	4 Hours	1 Hour	2 Hours	4 Hours
Fresh	0.1	70	72	95	82	92	97
	0.05	70	72	90	77	77	92
	0.01	50	42	55	35	40	72
24 Hours	0.1	0	35	52	0	20	55
	0.05	5	32	45	2	7	15
	0.01	0	2	0	0	0	0
48 Hours	0.1	5	22	60	0	0	7
	0.05	10	22	22	2	2	2
	0.01	0	2	10	0	0	2

which were then placed individually on top of small cylindrical screen holding cages containing 25 female house flies from a laboratory colony that was highly resistant to DDT. After 24 hours these pads were replaced with others dipped in unpoisoned honey. Knock-down counts were made after 24 hours and mortality counts after 48 hours.

The results of these tests are shown in table 1. Only the results obtained at the 5 per cent concentration are presented for compounds that caused low mortality at all concentrations.

The most effective toxicants were TEPP, sodium fluoroacetate, sodium arsenate, and sodium arsenite, all of which at a concentration of 0.5 per cent or less, both with and without malt, caused 84 to 100 per cent kill in 48 hours. Similar results were obtained with 1 or 2 per cent of sodium fluosilicate in both types of solution, and of ammonium bifluoride and sodium fluoride in malt solution. In most cases the addition of malt increased the kill. Mortalities of flies feeding on unpoisoned malt-water solutions never exceeded 5 per cent in 48 hours.

With TEPP in a malt solution, 96 per cent mortality resulted at a concentration of 0.1 per cent, and complete mortality at 0.2 per cent. Similar kills were obtained with 0.25 per cent of sodium fluoroacetate, 0.5 per cent of sodium arsenate, and 1.0 per cent of sodium arsenite. With TEPP, mortalities decreased considerably at the higher concentrations, indicating a repellent effect. A similar repellency with water solutions of some of the other materials was overcome by the addition of malt.

Since TEPP loses its toxicity rapidly when added to water, tests were conducted to determine the durability of this insecticide in water solutions containing 5 per cent of blackstrap molasses or malt as an attractant. Cotton pads, 1 inch square, were treated with 2 ml. of such solutions containing different percentages of TEPP and placed on the tops of the cages as previously described. Flies were exposed for 1, 2, and 4 hours, and mortality counts were made after 24 hours.

As shown in table 2, the freshly prepared baits containing blackstrap molasses were slightly more effective than those containing malt. All preparations lost much of their effectiveness in 24 hours, but the loss was slightly less in the malt than in the molasses baits. After 48 hours the molasses baits were almost completely ineffective, whereas the higher concentrations of TEPP in malt still showed some effectiveness.

FIELD TESTS WITH SODIUM ARSENATE BAITS.—Tests were conducted in three unscreened dairies to determine whether baits containing sodium arsenate would provide satisfactory control of house flies. Blackstrap molasses was used as the attractant in one dairy, malt in another, and in the third dairy blackstrap molasses in half the pans and malt in the others. All baits contained 2 per cent of sodium arsenate, 48 per cent of water, and 50 per cent of attractant. Ten metal pans 11 inches in diameter and 4 inches deep were partially filled with 2,000 grams of the baits and placed at locations inside each of the buildings where flies were most

numerous. Most of the pans were on the floor, but an occasional one was set on top of filled feed sacks in the storage room. Fresh bait was put out once each week. Each pan was covered with hardware cloth of 0.25-inch mesh to prevent domestic animals from taking the bait.

The technique of determining abundance consisted of counting the flies that alighted on a piece of hardware cloth laid over two petri dishes containing equal parts of malt and water. The dishes were always exposed in the location where the density of flies was greatest. Counts were made on 3 days before the tests were started and on 2 to 5 days each week while the bait pans were in operation. The degree of control was based on the difference in the counts of flies before and at various intervals after treatment. Results of the tests are summarized in table 3.

Table 3.—Effectiveness of sodium arsenate attractant baits in pans in controlling house flies in three dairy barns, 1952.

Attractant	Date of Record: Pre-treatment	Date of Record: Post-treatment	Average Fly Count	Per Cent Control
Blackstrap molasses	May 8–12	—	173	—
		May 13–16	35	80
		19–23	19	90
		26–29	18	90
		June 2–6	30	83
Malt	June 3–5	—	853	—
		June 6	96	89
		9–13	73	91
		16–20	30	96
		23–26	29	97
Blackstrap molasses and malt	June 13–16	—	248	—
		June 17–20	74	70
		23–27[1]	80	68
		30–July 4	17	93
		July 7–11	27	89

[1] Bait spoiled.

Reductions of 49 to 89 per cent occurred in each of the dairies during the first 24 hours after the bait pans were placed in operation, and the control gradually increased to 90 per cent or above during the second or third week. In the dairy where both attractants were used there was a marked increase in fly abundance at the start of the second week, but this was attributed to spoilage of the bait. Within 2 days after fresh bait was introduced, the fly populations again declined and excellent control (89 to 93 per cent) was maintained during the remaining 2 weeks of the test.

FIELD TESTS WITH TEPP BAITS.—Additional tests were run in four dairies with baits containing TEPP. Since this insecticide loses its toxicity rapidly in water solutions, pans were not employed to expose the bait. Instead, water solutions containing 0.05 per cent of the toxicant and 3.0 per cent of blackstrap molasses were sprinkled on the floors along walkways, entrances to the feed rooms, and other locations where flies congregated. In two of the dairies 0.3 per cent of lindane was also included in the formulation. Applications were made in strips 4 to 6 inches wide with a garden sprinkling can that had half the holes in the sprinkler head closed to reduce the rate of flow. Three gallons of solution were used for each treatment. In one dairy treatments were made daily for 15 days and five times weekly thereafter, and in the others four or five applications were made weekly. Treatments were not made on most week ends. Fly counts for estimates of control were made at least five times each week in the manner previously described for the sodium arsenate tests. The results of the tests are given in table 4.

Table 4.—Effectiveness of baits applied with a sprinkling can for the control of house flies in open dairies, 1952. All baits contained molasses.

Dairy No.	Average Flies Before Treatment	Date of Treatment or Observation	Number of Treatments	Per Cent Control: Range	Per Cent Control: Average
		TEPP Bait			
1	481	March 28–April 4	8	1–82	57
		April 5–11	7	75–97	92
		14–18	5	84–99	94
		21–25	5	83–93	89
		28–May 2	5	94–97	95
		May 5	—	88	88
		6–9	—	39–89	64
		12	—	40	40
2	417	May 12–16	4	71–97	86
		19–23	5	41–92	75
		26–29	4	87–95	91
		June 2–3	2	79–94	87
		5–8	—	67–68	68
		TEPP-Lindane Bait			
3	136	June 9–13	5	85–93	89
		17–20	5	82–93	90
		24–27	5	82–91	85
		30–July 1	2	86–92	89
		July 4	—	87	87
4	287	June 9–13	5	8–91	48
		17–20	5	38–84	66
		24–27	5	53–88	71
		30–July 3	4	49–80	67
		July 4	—	80	80
		7	—	61	61
		9	—	38	38

Repeated applications of these baits gave a high degree of control in all the dairies except one of those treated with the TEPP-lindane-molasses mixture. In this dairy an unusually large breeding

area near the treated building could be partially responsible for the poorer control. However, the addition of lindane did not materially increase the effectiveness of the bait in either dairy. The infestation always increased over the week ends, when no insecticide was applied, and particularly after the treatments were discontinued, indicating that regular applications are necessary to maintain good control. Incidental observations showed a marked reduction in larval abundance as well as in adult activity in and around manure piles.

On two occasions severely affected flies of both sexes were collected within 1 hour after the TEPP had been applied, and all of them died within 24 hours. In similar collections 5 to 6 hours after treatment 33 per cent of the flies recovered, most of which were females. These results emphasize that TEPP is highly toxic for only a short time and must be applied frequently to give satisfactory control.

DISCUSSION.—The baits employed in these tests were more effective than any other treatments that have been tried during the last 3 years. Since none of the chlorinated hydrocrabon insecticides had been effective in the dairies, all of them were heavily infested with resistant strains of flies at the outset of the bait tests. The one in which the sodium arsenate-malt formulation was employed consistently has had the highest fly population in the area and was selected to give this treatment a severe test.

Combining sodium arsenate or TEPP with an attractant to form a bait is a logical way to use these two materials in fly control. Both of them are highly toxic to man, so must be handled with care. No atomization need occur with either method of application described, for both treatments can be used on the floor or close to it where the majority of the flies feed. The use of an attractant is essential with sodium arsenate, as this compound is effective only as a stomach poison. Neither of the baits used in the dairy tests showed any repellency, whereas some of the space sprays tried recently in the same dairies drove a large part of the population outside. Moreover, the equipment required for either type of treatment is very cheap, easy to obtain, and requires very little maintenance.

The use of sodium arsenate baits in pans appears to have several advantages over applications of TEPP by the sprinkling-can method. It gives better control over a much longer time and does not need to be replaced so often. The control equaled, or nearly equaled, that formerly obtained with DDT residual sprays in these dairies. In addition, the pans are safer to use, because coarse wire covers prevent large animals from reaching the bait. However, they should be fastened securely to stationary objects or wide wooden panels to prevent their being tipped and contents spilled. TEPP was not tried in the pans, because it loses toxicity so rapidly that fresh bait would be required frequently. There is also a possibility that flies exposed to sublethal dosages of the insecticide would develop resistance to it.

SUMMARY.—Laboratory and field tests were run to evaluate bait formulations as a means of controlling resistant house flies, *Musca domestica* L. In laboratory tests TEPP, sodium fluoroacetate, sodium arsenate, and sodium arsenite proved to be the most effective of 15 water-soluble toxicants. Concentrations of TEPP above 0.5 per cent were somewhat repellent, both in water and malt-water solutions. Some of the other materials showed repellency at a concentration of 5 per cent in water alone but not when an attractant was added.

Baits in open metal pans were tested in three dairies. The baits contained 2 per cent of sodium arsenate, 50 per cent of either blackstrap molasses or malt, and 48 per cent of water. A reduction in fly abundance ranging between 49 and 89 per cent occurred during the first 24 hours, and the control gradually increased to 90 per cent or above during the second or third week of the test.

Two dairies were treated with water solutions containing 0.05 per cent of TEPP and 3 per cent of blackstrap molasses. The same formulation plus 0.3 per cent of lindane was used in two others. These solutions were applied with a garden sprinkling can on the floors at locations where flies congregated. Applications were made daily for 15 days and five times weekly thereafter in one dairy and four or five times each week in the others. A high degree of control was obtained in

all the dairies except one of those treated with the TEPP-lindane mixture.

The sodium arsenate bait set out in pans seemed to have several advantages over TEPP applied with a sprinkling can. It gave better results with less labor and material, and is probably a safer method to use.

Life History and Control of Scales on Apples in North Carolina[1]

GEORGE F. TURNIPSEED and CLYDE F. SMITH

Forbes scale, *Aspidiotus forbesi* Johns., is the major scale found on apples at elevations below 3,000 feet in the apple growing section of western North Carolina. Life history and seasonal history studies for the past three years show that this insect has two generations per year in North Carolina. It overwinters as an adult female which begins giving birth to living young the last of May. Peak emergence of spring brood occurs between June 10 and July 10. By late July the first generation is completed. Peak emergence of the summer brood occurs between August 10 and August 30. Overwintering insects are females of this generation (Fig. 1). This insect infests the trunk, branches, twigs and fruit. Unlike oystershell and scurfy scale, the first brood crawlers can infest the fruits; however, the fruits are usually infested with second brood crawlers.

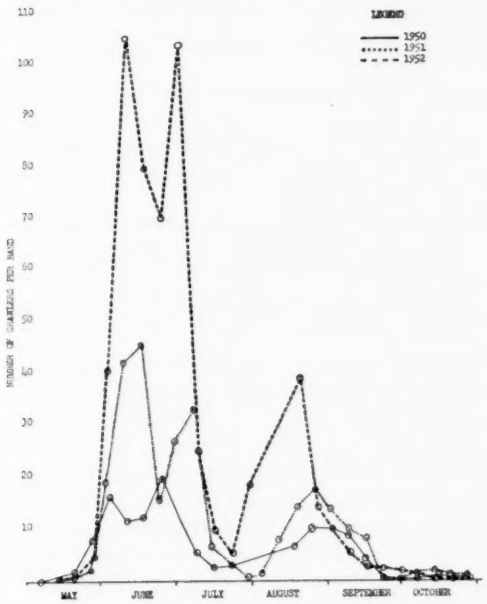

FIG. 1.—Seasonal History of Forbes Scale, 1950–1952 inclusive.

Trees are injured by the feeding of the insects which remove plant sap, thus weakening the tree. Injury is rarely fatal to trees, but on producing trees, a large share of apples are culls because of scale. One can detect infested fruit by a reddish discolored ring around each scale. This is more pronounced on yellow varieties than on red varieties.

During the 1950 season several spray programs were applied throughout the season in a block of Delicious and Stayman apples uniformly infested with Forbes scale (Table 1). Programs 1 and 6 (parathion programs) were highly effective against Forbes scale, giving clean fruit, and practically eliminating in one season all scale from the heavily infested trees. Program 2 was ineffective against scale on fruit and on trees. Program 3 (a combination of DDT and parathion) gave clean fruit and greatly reduced scale population on the trees. Oil at 2 per cent applied in dormant or delayed dormant gave commercial control of Forbes scale in 1951 and 1952 (Table 2). This scale can be kept under control with one thorough application of oil per year.

Oystershell scale, *Lepidosaphes ulmi* (L.), is a serious pest of apples at the higher elevations in western North Carolina. Fortunately, infestations are localized. Life history and seasonal history studies 1950 and 1952 show that this insect has two generations per year in North Carolina. This insect overwinters in the egg stage under the female scale covering. The over-wintering eggs begin to hatch

[1] Contribution from the Entomology Department, N. C. Agricultural Experiment Station, Raleigh, N. C. Published with the approval of the Director of Research as paper No. 476 of the Journal Series.

Table 1.—Forbes scale results—1950.

PROGRAM[1]	PER CENT SCALEY FRUIT AT HARVEST	PER CENT LIVING SCALES DEC. 1950
1[2] parathion	0.0	0.2
2[3] DDT	18.0	51.8
3[4] parathion and DDT	0.0	9.6
4[5] lead arsenate	2.5	41.4
5[6] dormant only	10.0	40.7
6[7] parathion	0.02	0.6
7 Check	18.0	40.7

[1] All programs, except No. 7 (check) had a dormant application of oil (2 gal./100) plus sodium dinitro ortho cresylate (19 per cent), (1 qt./100).
[2] Program 1 consisted of the dormant spray plus 5 applications of parathion (15 per cent w.p.—1.5 lbs./100) commencing with the pink spray.
[3] Program 2 consisted of the dormant spray plus 4 applications of DDT (50 per cent w.p.—2 lbs./100) commencing with the "first cover" spray.
[4] Program 3 consisted of the dormant spray plus 1 application of parathion (15 per cent w.p.—1 lb./100) in the "pink" spray and 4 applications of parathion (15 per cent w.p.—.75 lbs./100) plus DDT (50 per cent w.p.—1 lb./100) commencing with the "first cover spray."
[5] Program 4 consisted of the dormant spray plus 6 applications of lead arsenate (3 lbs./100) commencing with the "calyx cup" spray.
[6] Program 5—dormant spray only.
[7] Program 6 consisted of the dormant spray plus 5 applications of parathion (15 per cent w.p.—1.5 lbs./100) commencing with the "pink" spray. No fungicide was used at any time.
Program 7—a complete check.

the first week in April, or between the silver tip and pre-pink stage of apple development. Hatching continues until the first week in May and is completed by pink to full bloom stage of development of the apple. The crawlers settle on branches, twigs and trunk soon after emergence. The life cycle of the first or spring brood is completed late in June. The summer brood of crawlers infests trunk, branches, twigs and fruit; it occurs in July. This second brood develops into adults by the last of August and begins laying eggs in September. The adults have completed egg laying by late fall. Oystershell scale often kills young trees. On trees in production, many of the apples may be culls due to scaley fruit.

Several species of parasites and predators attack oystershell scale and may be responsible for a high degree of control in heavily infested orchards.

An experiment was conducted in a heavily infested commercial apple orchard in Haywood County in 1950 in which from 5 to 15 trees were sprayed with each material (Table 3). Treatment 6 (two applications of oil) caused the scales to drop off early in the spring and gave complete control on this plot throughout 1951. From observation and fruit counts, treatments 2 and 3 were very effective. This could be expected because the delayed dormant oil was applied only 2 weeks before crawler emergence.

Table 2.—Forbes scale experiment—1951.

TREATMENT	DATE OF APPLICATION	MATERIAL PER 100 GALLONS	PER CENT SCALEY FRUIT AT HARV. 10-9-51	PER CENT LIVING SCALE DEC. 1951
1[1]	3-2[1]	2 gal. oil[2] plus 1 qt. dinitro[3]	3.5	25.1
2	3-10[1]	2 gal. oil[2]	2.5	7.1
3	4-5	1.5 lbs. 15% parathion	25.75	35.3
4	4-5	1 lb. 27% EPN 300	29.25	54.6
5	4-5	8 oz. merthon[4]	59.75	49.7
6	4-5	2 lbs. malathion 25% w.p.[5]	50.75	56.4
7	4-5	8 oz. G 22008[6]	36.25	54.4
8		Check	30.75	58.4
9	4-5	2 lbs. C 1006[7]	57.00	53.3
10	4-5	3 lbs. 6% BHC	26.00	49.3

[1] 3-2-51 dormant spray; 3-10-51 delayed dormant spray.
[2] Oil furnished by Shell Chemical Corporation.
[3] Sodium dinitro ortho cresylate (19 per cent) furnished by E. I. DuPont Co.
[4] Mercurated pentaethyl triphosphate (10%), pentaethyl triphosphate and other related organic phosphonic esters (89 per cent), inert ingredients (1 per cent), furnished by Central Chemical Corp.
[5] Malathion furnished by American Cyanamid Co.
[6] G 22008 (1 phenyl-3-methyl-pyrazalyl-(5-dimethyl-carbonate) furnished by the Geigy Co.
[7] C 1006 (dinitro capryl phenyl crotonate) furnished by Rohm and Haas Co.

Table 3.—Oystershell scale sprays—1950.

PLOT	MATERIAL PER 100 GAL.	STAGE OF GROWTH	DATE OF APPLICATION
1	DN 289 2 qts.[1]	Dormant	2-15-50
2	DN 289 2 qts. 3 gal. oil[2]	Dormant Delayed Dormant	2-15-50 4-3-50
3	3 gal. oil	Delayed Dormant	4-3-50
4	2 gal. oil plus 1 qt. dinitro[3]	Dormant	2-15-50
5	Elgetol 318 2 qts.[4]	Dormant	2-15-50
6	3 gal. oil 3 gal. oil	Dormant Dormant	2-15-50 3-3-50
7	DN 289 1 gal.	Dormant	3-3-50
8	Check (no spray)		

[1] Material furnished by Dow Chemical Company.
[2] Material furnished by Shell Chemical Corporation.
[3] Sodium dinitro ortho cresylate (19 per cent) furnished by E. I. DuPont Co.
[4] Material furnished by California Spray Chemical Corporation.

Scurfy scale, *Chionaspis furfura* (Fitch), is a serious pest of apples at the higher elevations. Fortunately there is only one known serious infestation of this pest in western North Carolina. Life history and seasonal history studies during 1952 show that this insect has two generations per year in North Carolina (Fig. 2). This insect overwinters in the egg stage under the female scale covering. The overwinter-

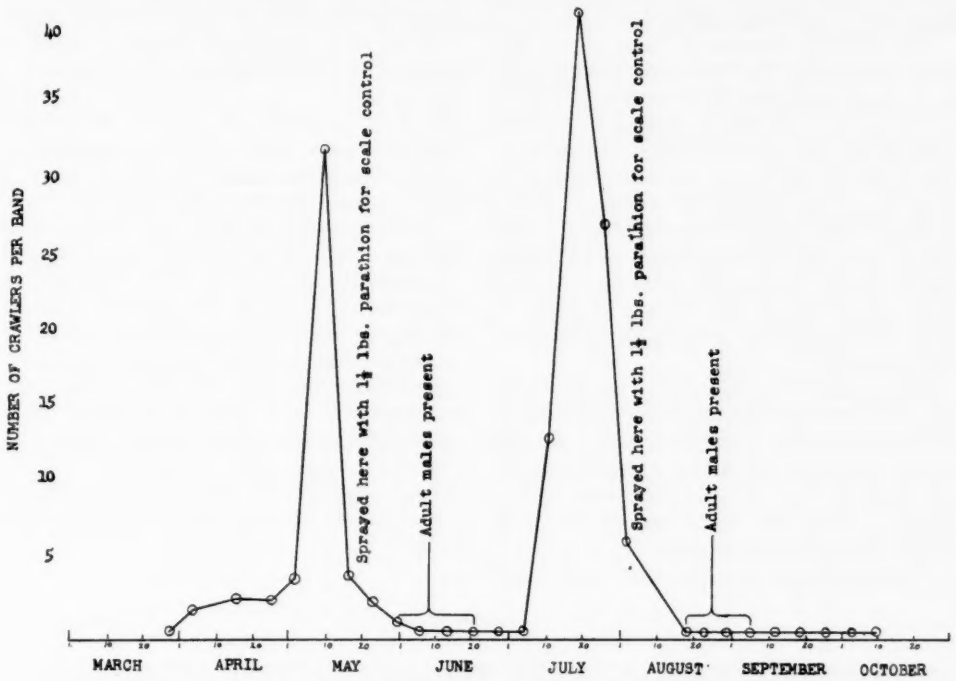

FIG. 2.—Seasonal History of Scurfy Scale—1952. Valle Crucis Orchard.

ing eggs began hatching April 1 with peak emergence occurring about May 9. All crawlers of the overwintering or first brood had emerged by June 6. Those emerging in early April had completed the first molt by May 10 and the second molt by June 7 and began depositing eggs by June 28. No crawlers emerged from June 6 to July 4.

Adult males appeared from the first brood May 30 and continued to June 20 (Fig. 2). The summer or second brood of crawlers began emerging between July 4 and 11 with peak emergence occurring July 18, Crawler emergence declined rapidly after July 18; none were present after August 18. Crawlers that emerged July 4 had completed their first molt by August 18 and the second molt by September 6 and began depositing their overwintering eggs October 3. Adult males of this brood appeared August 18 and con-

Table 4.—Scurfy scale results—1952.

Program	Insecticide Used			Per Cent Scaley Fruit at Harvest
	Kind	No. Applications	Amt./100 Gals.	
1	Oil	2 D.	3 gals.	
	Lead Arsenate	3	3 lbs.	0.00
2	Oil	1 D.D.	3 gals.	
	Lead Arsenate	3	3 lbs.	5.50
3[1]	Parathion	3	1.5 lbs.—15% w.p.	8.25
4[1]	Elgetol	1	1.5 qts.	
	Oil	1	3 gals. 83% Emul.	
	Lead Arsenate	3	3 lbs.	
	Parathion	3	1.5 lbs.—15% w.p.	0.00
5	Check—no treatment		———	99.00

[1] 1 application of parathion in pink stage for aphids before scale crawlers appeared.

tinued through September 5.

The feeding insects remove plant sap, thus weakening the tree and killing large and small branches. This results in heavy pruning of dead wood and in a gradual decline and death of the tree. On producing trees, a high per cent of the apples may be culls because of scales on fruit. During 1952 several complete spray programs were applied in a block of Delicious apple trees uniformly heavily infested with scurfy scale. As shown in table 4, each of these spray programs gave effective control.

SUMMARY.—Experimental results during 1950 indicate that Forbes scale can be controlled with parathion used in the cover sprays or with 2 per cent superior oil used in the delayed dormant spray. DDT used in the cover sprays was ineffective against Forbes scale.

Experimental results on oystershell scale during 1950 indicate that two applications of a 3 per cent dormant spray oil applied 2 weeks apart will clean up a heavy infestation. One application of a 2 per cent superior oil applied as delayed dormant each year will produce commercially clean fruit and keep the oystershell scale population at a minimum.

Experimental results on scurfy scale during 1952 indicated that heavy infestations can be cleaned up with two applications of a dormant oil applied 2 weeks apart, or with one application of a dormant oil followed by two applications of parathion when the scales are in the crawler stage. Oil as a delayed dormant spray or parathion (two applications during the crawler stage) gave only fair control. These applications might be satisfactory in orchards having only a light infestation.

Dehydrochlorination as a Measure of DDT-Resistance in House Flies

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The measurement of the degree of house fly resistance to DDT and to other halogenated hydrocarbon insecticides is accomplished in many different ways, depending upon the experimenter's choice of a suitable technique for the application of the chemical and of appropriate means for the evaluation of data.

In some cases the insecticide is applied topically to a selected body region of the insect by various methods. In other cases, groups of flies are exposed to known residual deposits of the toxicant for various lengths of time or to space sprays in chambers of various sizes.

Effectiveness is ordinarily measured in terms of the dosage or the concentration of an insecticide required to kill a certain percentage of the test insects, *e.g.*, the LD_{50}. Sometimes the criterion of effectiveness is based on the time required to produce certain effects, such as knockdown, paralysis, or prostration, with a known dosage of the toxicant.

All the above methods have demonstrated DDT-resistance successfully, but resistance comparisons of a given series of house fly strains showed marked discrepancies largely dependent upon the method used by different laboratories. Decker & Bruce (1952) have attributed some of these discrepancies to a sampling error in technique in collecting fly eggs and to other variable factors involved in rearing.

In many cases the use of different types of solvents may alter results significantly. For instance, Busvine (1951) has shown that one particular strain of flies resisted a dose of DDT in oil 16 times the dosage tolerated by a susceptible strain, whereas the difference was 300-fold with DDT in acetone. More recently, Hoskins *et al.* (1952) demonstrated that on glass surfaces lindane deposits from petroleum ether or benzene formed chunky crystals and were highly toxic to house flies; but from chloroform, flat plates predominated and were only slightly toxic.

Dosage-mortality curves have been widely used as the basis for measuring DDT-resistance in house flies, but the

Table 1.—Recovery of DDT and DDE from various strains of house flies at 2-, 4-, and 8-hour intervals after topical application of 6.8 micrograms DDT per fly. Results are based on five replications.

Fly Strains (In Order of Increasing Resistance[1])	Interval to Extraction (Hours)	Recovered (Micrograms per Fly)					
		Unabsorbed DDT		Absorbed DDT		Metabolized DDT (DDE[2])	
		Mean	Stand. Dev.	Mean	Stand. Dev.	Mean	Stand. Dev.
NAIDM 1948	2	5.73	0.03	1.17	0.07	0.05	0.02
	4	5.38	0.07	1.50	0.02	0.07	0.01
	8	4.96	0.12	1.73	0.16	0.08	0.02
Yuma	2	5.51	0.13	1.15	0.01	0.29	0.03
	4	5.20	0.11	1.47	0.12	0.49	0.10
	8	4.67	0.15	1.99	0.14	0.80	0.05
Roberds	2	5.35	0.11	1.15	0.36	0.54	0.03
	4	4.72	0.13	0.91	0.15	1.25	0.10
	8	3.97	0.06	2.66	0.20	2.06	0.14
DDT-45	2	5.33	0.14	0.86	0.05	0.52	0.02
	4	4.77	0.18	1.11	0.11	0.77	0.07
	8	4.18	0.26	1.78	0.08	1.47	0.05
Penitas	2	5.36	0.13	1.08	0.12	0.72	0.08
	4	4.75	0.08	1.64	0.05	1.27	0.06
	8	3.98	0.21	2.08	0.11	1.81	0.10

[1] Based on LD_{50} by topical application.
[2] DDE figures expressed as molecular equivalents of DDT.

main objection to this procedure lies in the fact that the amount of insecticide which penetrates the insect cuticle is not always proportional to the dosage applied. Sternburg *et al.* (1950), Perry & Hoskins (1951a), and Winteringham[1] have shown that the rate of absorption of DDT by house flies does not increase in proportion to increasing topical dosages of the toxicant. It has also been demonstrated (Perry & Fay)[2] that when large dosages are used, circa 50 micrograms per fly, in some cases a twofold increase in topical dosage will result in only slight or no increase in absorbed DDT, and consequently in little or no increase in mortality during the 24-hour period of observation. This is not surprising if application of the insecticide is made to a restricted area of the integument so that at high dosages superimposition and aggregation of DDT particles might take place. Absorption from thick deposits might be expected to be less efficient since only the inner portion of the insecticide has access to the integument. This effect will accentuate the spread in apparent resistance among strains of flies, especially if application is made topically with a volatile solvent.

Previous investigations (Perry & Hoskins, 1951b; Sternburg *et al.*, 1950; and Winteringham *et al.*, 1951) have shown that resistant flies are able to metabolize DDT to the relatively nontoxic ethylene derivative, 2,2-bis(*p*-chlorophenyl)-1,1-dichloroethylene, (DDE). On the basis of this knowledge it seemed desirable to explore the possibility of standardizing a laboratory technique for measuring DDT-resistance based on the amount of DDT absorbed and its rate of conversion to DDE.

METHODS.—The method of treatment and the analytical procedure used in this work have been described in detail previously (Perry & Hoskins 1951a, 1951b). Briefly, the method was as follows: Groups of 30 to 50 adult female flies, 3 to 4 days old, were given topical doses of *p,p'*-DDT in benzene at a rate of 6.8 micrograms per fly. The treated flies were placed in 600 ml. covered beakers and were provided with food and water. At the end of 2, 4, and 8 hours the flies were rinsed in three successive 15 ml. volumes

[1] Winteringham, F. P. W. Metabolism of DDT by resistant house flies.
Presented at the Conference on Insecticide Resistance and Insect Physiology, December 8–9, 1951. University of Cincinnati, Cincinnati, Ohio.
[2] Unpublished data.

of n-hexane to remove the unabsorbed DDT. They were then thoroughly ground in the presence of a small amount of anhydrous sodium sulfate and extracted with carbon tetrachloride for 30 minutes. The extract was filtered off and the filtrate was chromatographed through a sulfuric acid-Celite column, similar to that described by Davidow (1950). The external and internal extracts were each analyzed for DDT and DDE by the procedure of Schechter *et al.* (1945).

Since temperature has been shown to influence the conversion of DDT to DDE (Vinson & Kearns, 1952; Roth & Lindquist, 1953) biological procedures were carried out at 25° C. and 70 per cent relative humidity.

RESULTS.—The amounts of DDT absorbed and of DDE formed at 2-, 4- and 8-hour intervals after topical application of 6.8 micrograms DDT per fly are shown in table 1. The results are average values of three to five tests with each of five strains of flies ranging from susceptible to highly resistant. The amount of DDT absorbed at the indicated interval corresponds to the sum of the actual amounts of DDE and of unchanged DDT found internally in the tissue extracts. It may be noted (Fig. 1) that the amount of DDT absorbed in the first 2 hours was fairly uniform for all strains with one exception, *i.e.*, the DDT-45 strain which absorbed DDT at a somewhat slower rate. Greater differences in absorption rates were manifested at the 4-hour and 8-hour intervals. The most pronounced change in absorption at the 8-hour interval was noted in the susceptible strain (NAIDM) as indicated by the more flattened absorption curve (Fig. 1). At this time many flies were dead and the rest were moribund. This suggests that absorption is slowed down considerably after death of the insect.

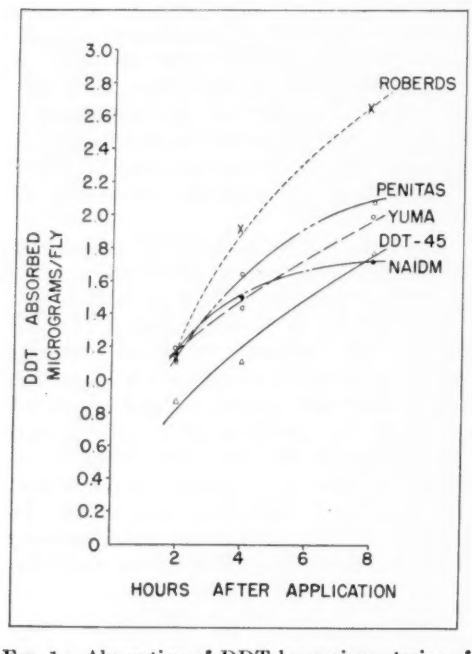

FIG. 1.—Absorption of DDT by various strains of house flies at intervals of 2, 4, and 8 hours after topical application of 6.8 micrograms DDT per fly.

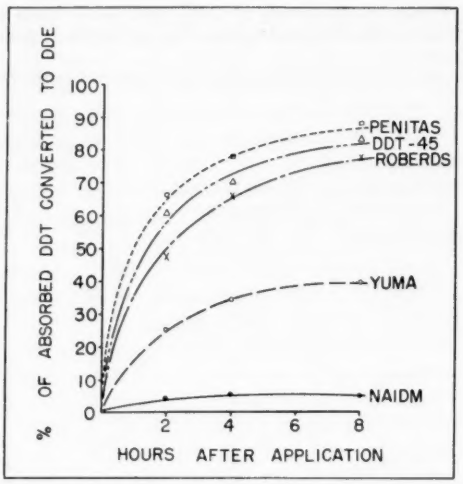

FIG. 2.—Percentage of absorbed DDT metabolized to DDE by various strains of house flies at intervals of 2, 4, and 8 hours after topical application of 6.8 micrograms DDT per fly.

In general, the data in table 1 indicate no correlation between absorption of DDT and resistance since the resistant Roberds strain absorbed more DDT than either the susceptible NAIDM strain or the more resistant Penitas strain. In certain cases, however, absorption rates of DDT may influence the apparent resistance of a strain, as, for example, in the DDT-45 strain which is to be discussed more fully in another paper.

The amounts of DDE formed at each interval after treatment (Table 1) do not actually constitute the criterion of the degree of resistance in any given strain of flies since these values are partially dependent upon the amounts of absorbed DDT. The determining factor appears to be the percentage of DDE formed from

Table 2.—Absorption and metabolism of DDT at intervals of 2, 4, and 8 hours, and 24-hour mortality in various strains of house flies after topical application of 6.8 micrograms DDT per fly. Thirty to 50 adult female flies per test. Average of five tests.

Fly Strain	Interval to Extraction (Hours)	DDT Absorbed (Micrograms per Fly)	DDT Metabolized (DDE)[1]		Per Cent Mortality in 24 Hr.
			Micrograms per fly	Per Cent of Absorbed DDT	
NAIDM	2	1.17	0.05	4	100
	4	1.49	0.07	5	
	8	1.72	0.08	5	
Yuma	2	1.18	0.29	24	74
	4	1.44	0.49	34	
	8	1.99	0.79	40	
Roberds	2	1.15	0.54	47	35
	4	1.91	1.25	65	
	8	2.66	2.06	77	
DDT-45	2	0.86	0.52	60	12
	4	1.11	0.77	69	
	8	1.77	1.47	83	
Penitas	2	1.10	0.72	65	10
	4	1.64	1.27	77	
	8	2.08	1.81	87	

[1] DDE figures are expressed as molecular equivalents of DDT.

the amount of DDT available within the body of the insect, disregarding unknown factors such as storage of unchanged DDT in various tissues and the conversion of DDT to unknown metabolites, which might play a role in the overall physiological mechanism of resistance.

The percentages of absorbed DDT converted to DDE at various intervals are shown in figure 2. The relationship between per cent DDE formed and mortality of flies selected at random from the same population is shown in table 2, and is plotted as per cent survival in figure 3. Good correlation is shown between the ability of house flies to detoxify DDT and their survival. Hence, the degree of resistance can be measured quantitatively as a function of the detoxification potential of a given strain.

It is proposed that an index be adopted for measuring the degree of DDT-resistance in various strains of flies. The index figure would correspond to the percentage conversion of absorbed DDT to DDE. This DDT-resistance index is more accurately determined 2 hours after application of a measured dosage of approximately 5 to 10 micrograms of DDT per fly for the following reasons: (1) All treated flies are still alive, (2) differences in the absorption of DDT are less variant between strains, and (3) greater differentiation is possible among strains which can metabolize approximately equal amounts of DDT after an extended period of time, especially if the dosage applied is sublethal.

According to this technique the strains of flies used in this study may be classified as follows:

Fly Strain	*Resistance Index*	*Resistance Level*
NAIDM 1948	0–5	Susceptible
Yuma	24	Moderately Resistant
Roberds	47	Medially Resistant
DDT-45	60	Highly Resistant
Penitas	65	Highly Resistant

The index for the susceptible strain is given as 0 to 5 because the amounts of

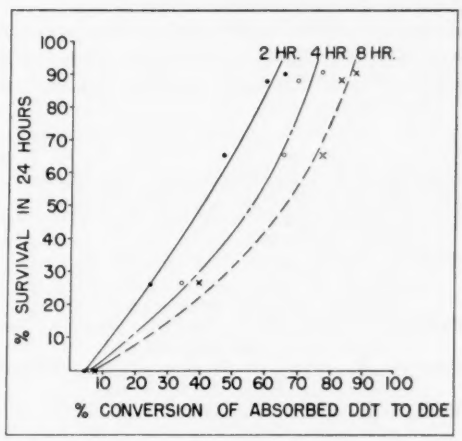

FIG. 3.—Curves relating percentage conversion of absorbed DDT to DDE at intervals of 2, 4, and 8 hours to 24-hour-survival in five strains of flies after topical application of 6.8 micrograms DDT per fly.

DDE obtained (0.03 to 0.07 micrograms per fly) are considered to be below the lower limit of accuracy of this method of analysis. However, greater sensitivity in the lower range can be obtained by making slight modifications in the Schechter-Haller method and by using microcells for color analysis.

From a practical viewpoint, it is safe to assume that a strain having an index of 0 to 10 is a susceptible strain and can be controlled with DDT following the usual recommendations.

Based on the strains tested, the following general classification is proposed as one measure of house fly resistance to DDT:

Resistance Index	*Resistance Classification*
0–10	None
11–20	Slight
21–35	Moderate
36–55	Medial
56–75	High
>75	Extreme

Resistance as measured by mortality is based on an all-or-none response of each insect to the chemical, and the results are satisfactory for purposes of practical control. In the method proposed herein resistance is measured by a graded response of each insect while it is still a living organism, and represents a more sensitive method for comparisons of the degree of resistance for laboratory or basic studies.

SUMMARY.—Various methods of application and criteria of effectiveness have been employed in measuring house fly resistance to DDT and to other halogenated hydrocarbon insecticides. Discrepancies in results from different studies can be attributed to variations in laboratory techniques and to the use of the dosage-mortality curve as the sole criterion for measuring resistance. The amount of DDT absorbed by flies is not always proportional to the dosage applied, especially if application is made in a volatile solvent. Hence, the unabsorbed insecticide plays no significant role in resistance. A method for measuring DDT-resistance based on the rate of dehydrochlorination of DDT is proposed. The method involves colorimetric determinations of DDT and DDE 2 hours after application of a measured dosage of the insecticide to the ventral thorax of individual flies. Good correlation is shown between dehydrochlorination rates and survival of flies. Resistance indices from 0 to 65 are given for five strains of flies ranging from susceptible to highly resistant. An index system of resistance classification is proposed.

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Resistance of Insects to Insecticides: the Metabolism of Injected DDT

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With the appearance of resistance by certain species of insects to several postwar insecticides has come the realization that resistance by most other species can be expected. The lack of alternate control measures and the consequent threat to the public health and food supply of the world have led many investigators to search for an explanation of the phenomenon so that remedial measures can be instituted.

The ability of resistant house flies, *Musca domestica* L., to metabolize DDT was first demonstrated by Sternburg, Kearns, and Bruce (1950). The product of metabolism was essentially 2,2-bis(*p*-chlorophenyl)-1,1-dichloroethylene, known as DDE, but a small amount of 2,2-bis(*p*-chlorophenyl) acetic acid, known as DDA, was also formed. The susceptible flies with which the resistant insects were compared were able to metabolize DDT only slightly, and the product of metabolism was neither DDE nor DDA. At that that time the authors "were not sure whether or not resistance is imparted to the fly by its ability to metabolize DDT rapidly after it has penetrated the cuticle." Later Sternburg & Kearns (1950) concluded that "the cause of resistance to DDT by certain strains of flies is due to the development of a mechanism by which DDT is detoxified to DDE in the cuticle-hypoderm and in the digestive tract before it has reached a vital site."

Perry & Hoskins (1950) and March & Metcalf (1950) found that both resistant and susceptible strains could metabolize DDT, but the resistant strains metabolized it at a faster rate. These authors reported that no DDA was demonstrated as a metabolite. In their opinion the resistance was due to the increased ability of the resistant insects to metabolize DDT. Lindquist *et al.* (1951), however, using C^{14}-labeled DDT and bioassay methods, found that both resistant and susceptible strains of flies metabolized absorbed DDT at the same rate to a product nontoxic to mosquito larvae. None of the metabolites were identified.

Perry & Hoskins (1950) reported that the ability of the resistant strain to metabolize DDT was completely inhibited by piperonyl cyclonene but this material had no effect on the metabolism of DDT by the susceptible strain. This seemed to indicate different metabolic systems in the two strains. Using the bromine analog of DDT, 2,2-bis(*p*-bromophenyl)-1,1,1-trichloroethane, labeled with radioactive bromine, Winteringham *et al.* (1951) largely confirmed the work of Perry & Hoskins (1950), but interpreted the results to mean that the metabolism was not sufficiently rapid to account for the successful resistance of the flies. Busvine (1951) also concluded that the dehydrochlorination mechanism does not fully account for the DDT resistance, and that one must postulate an additional defense mechanism. Perry & Hoskins (1951a, b) extended their work on the effects of synergists on DDT metabolism and the relation of detoxification to resistance. They found that "the extent of the reaction [the dehydrochlorination of DDT to DDE] is approximately proportional to the resistance as measured by the dosage needed for 50 per cent mortality by topical application to the thorax." They found that little DDT was absorbed by dead flies, but Hoffman *et al.* (1952) reported that the rate of absorption of DDT proceeds at about the same rate in dead as in living flies.

Chadwick (1952), summarizing the work on the physiology of resistance, stated that Perry (personal communication) had reported having found that some susceptible flies detoxified low dosages of DDT as rapidly as did resistant strains, indicating that increased detoxification might be a result of rather than a cause of resistance.

It is the purpose of this paper to present further evidence that the ability to metabolize DDT is not sufficient explanation for the resistance phenomenon, and

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to supplement the information on the physiology of resistance to insecticides contained in others papers in this series (Babers & Pratt 1950, Pratt & Babers 1950, 1953).

MATERIALS AND METHODS.—The Orlando-Beltsville resistant (R_{64}) and the Beltsville normal (SF) strains of house flies were used. All larvae were reared on standard Peet-Grady medium (Anonymous 1951). After emergence the adults were given a 50-50 mixture of powdered whole milk and sucrose *ad libitum*, with water also available. The resistant insects had been selected for resistance for more than 100 generations, and a high percentage of each population were essentially immune to DDT. Within 2 hours after emergence a number of adult flies of each generation were placed in cages heavily coated with DDT, the five solid walls having been painted with a saturated acetone solution of the insecticide. The sixth wall of the cage, constructed of screen wire, was dipped in the solution. The acetone was allowed to evaporate before the flies were introduced. The cages were cleaned and repainted for each generation. The adult flies remained in these cages until oviposition occurred several days later, and the eggs were then used to maintain the colony.

Measured quantities of DDT solutions were delivered by means of a standard 0.25-ml. tuberculin syringe, the plunger of which was driven by contact with a micrometer head (Trevan 1922). To prevent leakage, the syringe plunger was lightly greased with silicone-type stopcock grease. For topical applications a blunt-point 30-gauge metal needle was used. For injections a metal needle was cut off near the adapter, and a glass needle of the desired size drawn from Vycor tubing cemented to the adapter with beeswax. The glass needle was more satisfactory than a metal needle of comparable size, because when the tip became clogged with tissue it could readily be broken off.

The flies, anesthetized by carbon dioxide, were injected by inserting the needle through the postscutellum and directing it anteriorly into the thorax. Reagent-grade acetone was used as a solvent. A constant volume (0.216 cu. mm.) was injected, and the dosage of insecticide was varied by changing the concentration. The syringe was previously calibrated by weighing the mercury delivered and also by determining the copper present after an acetone solution of copper naphthenate had been injected into the flies. From these calibrations the injected dose was $0.216 + 0.004$ cu. mm.

For topical treatment the desired quantity of DDT in 1.18 cu. mm. of acetone was applied to the thorax of the anesthetized fly.

Adequate controls showed that the mortality of flies injected with 0.216 cu. mm. of acetone alone was less than 3 per cent. If the amount of acetone was increased to 0.5 cu. mm., the mortality was high.

Following injection the flies were held in beakers with gauze covers and were allowed to feed on cotton wet with skimmed milk. After the desired interval, the live flies were analyzed for DDT, DDE, and in some cases DDA by the Schechter-Haller (1945) procedure. The method is empirical and requires strict adherence to the adopted procedures.

Individual flies were analyzed when the amount of DDT injected was 20 micrograms or more. Pooled flies were analyzed when less DDT was used. An equal number of untreated flies were used as blanks.

In the first series of experiments the ether extracts of the flies were analyzed for DDA. Aliquots of the extracts were washed with alkali, which would remove DDA if present. After acidification of the alkali, the free acid could then be extracted and the DDA determined by the usual Schechter-Haller technique. It was found in control experiments that in dilute solution some DDT would dehydrochlorinate, even with ice-cold sodium bicarbonate, giving rise to false DDE values. For that reason the original ether extract was divided into aliquots and only part extracted for DDA. Since in no case was DDA found to be a metabolite, in later experiments the tissue extracts were not analyzed for that substance.

The solvent was removed at room temperature in a vacuum desiccator to minimize losses of DDT due to heat, and the samples were allowed to stand overnight over calcium chloride to ensure dryness before nitration. After nitration, the separatory funnels used for extraction should not be greased with silicone-type stopcock grease. In collaboration with

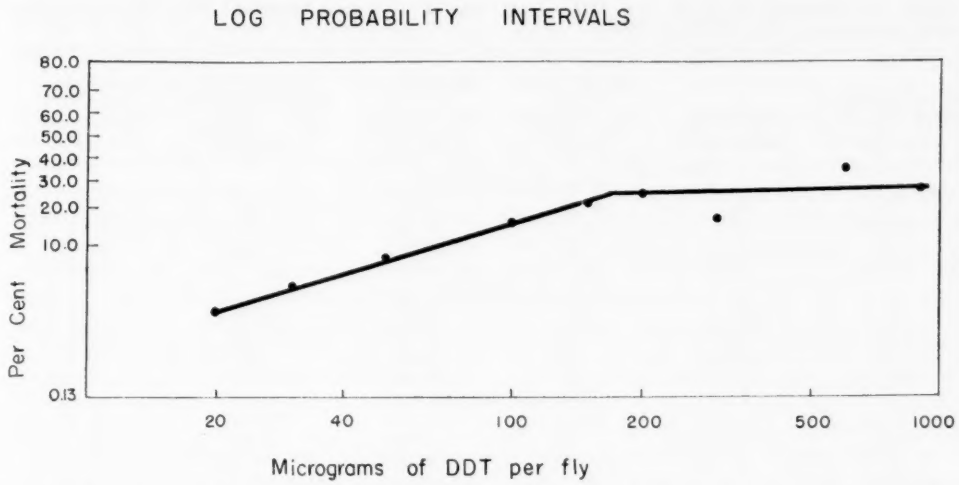

FIG. 1 —Per cent mortalities following application of DDT solutions to the thorax of female resistant flies.

Kearns and Sternburg it was found that the use of such grease often caused cloudiness and light colors in the final solutions. Cello-grease, the only other stopcock lubricant tried, caused no trouble.

The optical density of the final color was determined on a Beckman DU spectrophotometer. Readings were made at wavelengths of 520 and 595 millimicrons. The individual components DDT and DDE were determined according to the procedure for mixtures discussed by Weissberger (1949).

Owing to the inherent errors in the method for expected quantities of DDE or DDT less than 20 micrograms, the results of analyses varied by about ±8 per cent from the standard curves.

For each experiment the indicated dosage was injected or applied topically to 10 insects with 5 replications. The experiments were repeated three times with different populations of each strain. The results given are the averages of the several experiments.

RESULTS.—Attempts to determine the LD-50 for the resistant insects by topical applications of DDT in acetone solution were unsuccessful. The mortalities obtained 48 hours after application of DDT solutions of varying concentrations to the thorax of the female flies are indicated in figure 1.

When 1 microliter of an acetone solution containing 0.3 microgram of DDT was applied topically to individual susceptible female flies, the 24-hour mortality was about 50 per cent. When the

Table 1.—Recovery of DDE and DDT from tissues of female susceptible and resistant flies treated with 0.3 microgram of DDT per fly.

METHOD OF APPLICATION	STRAIN	PER CENT MORTALITY	MICROGRAMS OF DDE RECOVERED PER FLY	MICROGRAMS OF DDT RECOVERED PER FLY	PER CENT APPLIED DDT METABOLIZED TO DDE	TOTAL PER CENT RECOVERED AS DDT
		Flies dead after 24 hours				
Topical	SF	70	0.02	0.22	6.7	80.0
Injected	SF	42	.01	.22	5.3	76.8
		Flies dead after 24–48 hours				
Topical	SF	73	—	—	—	—
Injected	SF	59	0.01	0.12	4.7	43.4
	R_{64}	8	—	—	—	—
		Flies alive after 48 hours				
Topical	SF	—	0.08	0.02	29.7	36.6
Injected	SF	—	.07	.04	25.0	40.0
	R_{64}	—	.17	.03	62.3	78.3

Table 2.—Recovery of DDE and DDT from tissues of female resistant flies following injection of the indicated quantities of DDT.

Micrograms of DDT Injected per Fly	Per Cent Mortality	Micrograms of DDE Recovered per Fly	Micrograms of DDT Recovered per Fly	Per Cent of Injected DDT Metabolized to DDE	Total Per Cent Recovered as DDT
		Flies dead after 24 hours			
7.5	19.3	0.25	5.75	3.75	80.5
15.0	8.5	1.29	11.00	9.78	83.0
30.0	12.7	.11	26.46	.04	88.8
60.0	8.0	0	55.16	0	92.0
		Flies dead after 48 hours			
7.5	32.6	0.61	4.62	9.06	70.8
15.0	16.2	0.84	9.47	6.39	69.5
30.0	28.0	.13	23.96	.48	80.4
60.0	19.3	.05	46.86	.01	78.2
		Flies alive after 48 hours			
7.5	—	1.16	3.71	17.20	66.7
15.0	—	.82	7.64	6.19	57.7
30.0	—	.24	23.16	.92	78.2
60.0	—	0	48.52	0	81.0

same amount of DDT contained in about 0.216 microliter was injected, the 24-hour mortality was somewhat lower but the 48-hour mortality was higher. Following the application of this dosage to both susceptible and resistant flies, the tissues were analyzed, with the results indicated in table 1.

In other experiments larger dosages of DDT were injected into resistant insects. Analyses of tissue extracts from these flies are given in table 2.

Each group of 10 flies was held in a beaker for analysis after narcosis with carbon dioxide. After removal of the flies, the beakers were rinsed with ether, and the rinse from the five replications was combined and analyzed for DDT and DDE. Each value thus represents the amount of DDT or DDE recovered from five containers that held a total of 50 female resistant flies. The results are shown in table 3.

DISCUSSION.—The curve in figure 1 emphasizes the danger of attempting to extrapolate dosage-mortality curves in order to obtain an LD-50 value, especially with resistant strains. The results of these experiments were first interpreted to mean that, when increasing quantities of DDT were applied topically, the absorption system reached equilibrium with the metabolic system. On the basis of the work of Sternburg *et al.* it was further assumed that DDT was largely metabolized as soon as it was absorbed. To avoid any absorption effect it was decided to inject large doses of DDT. Winteringham *et al.* had injected the bromine analog, but only 0.6 microgram per fly. After the injection experiment it was apparent that:

(1) When DDT was applied topically, almost maximum mortality was obtained in less than 24 hours, but following injection it was 48 hours before the maximum was reached.

(2) In the resistant strain there was no apparent relation between dosage and mortality between dosages of 7.5 and 60 micrograms although at low dosages the mortality tended to be higher.

(3) At low dosages the percentage of DDT metabolized was much higher.

Table 3.—Micrograms of DDT and DDE recovered from beakers in which 50 female resistant flies had been held following injection of DDT.

Micrograms of DDT Injected per Fly	Experiment 1		Experiment 2		Experiment 3	
	DDT	DDE	DDT	DDE	DDT	DDE
7.5	16.6	1.06	8.4	0.6	45.5	0
15.0	15.6	1.24	34.9	0	11.9	0
30.0	85.3	0	53.0	0	55.1	0
60.0	82.3	0	55.3	0	31.6	0

(4) At the maximum dosage used no DDE was formed.

(5) Resistant flies were able to survive, seemingly unaffected, when relatively huge quantities of DDT were present internally. In the susceptible insects mortalities exceeded 95 per cent when 1 microgram of DDT was injected.

(6) Following the injection of DDT, both DDT and DDE were recovered from some of the beakers in which the flies had been held. It is assumed that the DDT and DDE were excreted through normal processes, but it is possible that the material was extruded from the wound made by the needle.

(7) The resistant strain metabolized more DDT to DDE than the susceptible strain, but a large percentage of the DDT injected into the susceptible insects was apparently metabolized to some as yet unknown metabolite.

The assumption that some of the DDT was metabolized to an as yet unknown metabolite is based on the failure to account for all the DDT theoretically applied. The copper naphthenate solution used to calibrate the syringe had a different viscosity from the DDT solution, and it is possible that an error in the delivery of DDT occurred. If less than the expected quantity of DDT was applied, the percentage recovery would of course be increased.

In none of the work so far reported has the ability of susceptible and resistant strains of flies to metabolize DDT been compared when the insects are in the same condition of poisoning. We have been unable to devise conditions in which such equality would exist, and in our opinion, until the strains are compared under such similar conditions of poisoning, the question of whether the increased ability of the resistant strain to metabolize DDT to DDE is a cause or result of resistance will be unanswered. It seems definitely established that increased ability to dehydrochlorinate an insecticide is not the only requirement for resistance, because strains resistant to DDT, which can be dehydrochlorinated, are also resistant to materials such as 1,1-dianisylneopentane, which cannot be dehydrochlorinated (Brown & Rogers 1950).

We are forced to conclude, therefore, that resistance in house flies is still an unexplained phenomenon.

SUMMARY.—The ability of a resistant strain of house flies, *Musca domestica* L., to metabolize DDT was compared with that of a susceptible strain following the topical application on or injection of measured dosages of DDT into individual insects. Analyses of tissue extracts showed that, at low dosages of DDT, more DDE was recovered from resistant insects than from susceptible ones. However, the susceptible insects were able to metabolize DDT to DDE and an unknown metabolite. At high dosages of DDT, the ability of the resistant strain to metabolize DDT was blocked to a considerable degree. It is therefore concluded that the resistance of house flies to insecticides is still an unexplained phenomenon.

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Some New Fly Repellents from Laboratory Screening Tests[1]

LYLE D. GOODHUE and ROY E. STANSBURY

After the discovery of DDT and other powerful insecticides that followed it, the battle against flies appeared to be won and indeed for several years there were very few house flies. This was not to last and soon resistant strains began to appear. Now resistant flies are more common than those with no resistance, and it is well known that each new insecticide can be used for only a relatively short period before it becomes much less effective. There are some exceptions such as the continuing high effectiveness of DDT against the horn fly. Other methods of fly control are again in order and one of these can be the use of repellents. Although not much has been done on fly repellents in the last 10 years, they are by no means new. The literature is replete with descriptions of proprietary mixtures and synthetic organic chemicals that have shown repellency in varying degrees. Also many methods of testing, too numerous to mention, have been used. Most of these are not very precise and are not capable of detecting small differences.

In this study, screening tests were first made against houseflies by a slight modification of the Kilgore (1939) "Sandwich-bait" method. Chemicals showing a high degree of effectiveness were then tested against stable flies on impregnated fabric over the hand in a manner similar to that commonly used to test repellents against mosquitoes. Later many chemicals not repellent to house flies have been tested against the stable fly to see if any had been overlooked.

MATERIALS AND METHODS.—House fly cultures continuously maintained by the official method were used as one of the test species. They were held in 10-inch cubical cages with glass fronts and sheet rubber backs. The backs had access holes that were closed by jar lids. These cages were provided with removable masonite bottom for ease in cleaning. The remaining three sides were covered with bronze fly screen. Generally, the flies were from 5 to 10 days old when used. Before the tests were started the bottoms of the cages were cleaned and clean glasses were placed in the front. The flies were not fed on the morning of the test, but were given a generous amount of food on the evening after the test and used only every other day for best results.

Our modification of the sandwich-bait method is briefly as follows: Heavy black molasses was spread thinly in two quarter-inch strips on 2 by 3 inch pieces of cardboard and dried at 110° F. for 3 to 4 hours to eliminate the tackiness. Strips of porous paper, 1 by 4 inches, cut from either white stencil backing tissue or lens paper were dipped in acetone solutions of the chemical and dried. The dosage on the strip was controlled by the per cent of chemical in the solution. The identification and dosage of the chemical was written on the strip in pencil. Most materials were soluble in acetone, but if not, water or some other volatile solvent was

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[1] Contribution from Phillips Petroleum Company, Bartlesville, Oklahoma.

Table 1.—Results of tests on some chemicals as repellents to houseflies

No.		Dosage (Per Cent)	Flies Feeding at Time Indicated (Minutes)							
			5	15	30	45	60	90	120	150
11	Butadiene-furfural copolymer	5	0	0	0	0	0	0	1	6
		1	0	32	27	0	1	17	4	5
14	High boiling amine mixture	5	0	0	0	0	0	0	0	1
		2.5	0	0	0	0	0	2	1	9
		1	0	1	6	9	15	12	depleted	
49	Diethyl isocinchomeronate	5	0	0	0	0	0	0	0	0
		1.25	0	0	0	0	0	0	0	0
		0.5	0	0	0	0	0	0	0	0
		0.25	7	50+depleted						
326	Di-*n*-propyl isocinchomeronate	5.0	0	0	0	0	0	0	0	0
		1.0	0	0	0	0	0	0	0	0
		.5	0	0	0	0	0	0	0	0
		.25	0	0	0	0	0	0	0	0
		.12	3	3	1	3	0	0	0	0
		.06	11	10	5	2	2	1	0	6
484	*tert*-Dodecylmercaptopoly-oxyethylene (11)	5	0	0	0	0	0	0	0	0
		1.25	1	0	0	0	0	0	0	0
		.62	1	2	0	0	0	0	0	0
		.31	9	18	2	2	depleted			
247	Ethylene thiocyanate	5	0	0	0	0	0	0	0	0
		1.25	0	0	0	0	0	0	0	0
		.62	0	0	0	0	0	0	0	0
		.31	0	0	0	0	0	0	0	0
		.15	1	1	0	0	1	0	0	0
178	High boiling amine residue	5	0	0	0	0	0	0	0	0
		1.25	0	0	0	0	0	0	0	0
		.62	0	0	0	0	0	0	0	0
		.31	0	0	3	4	4	2	1	3
		.15	1	0	11	5	5	1	0	depleted

used. About 1:00 p.m. the treated porous strips were stapled over the dried molasses and placed in the holder. The holders for these sandwiches were made of pieces of sheet aluminum 2 inches wide and finished 2.75 inches long after the ends were rolled to form a groove. Each holder was attached to a jar lid that fits the hole in the back of the fly cage. Since the holders were shorter than the sandwich, the card must be bowed to place it in the holder. In this curved position the porous paper strips were held firmly against the dried molasses. This was important because no spots were left where the flies could not reach the molasses. Thus prepared, each holder had two strips of molasses each covered by a treated strip of porous paper. The holders were placed in the back of the cages at about 1:30 p.m. at which time the flies were hungry enough to cover a strip immediately if the chemical was not repellent. The number of flies on each strip was recorded after 5 minutes, 15 minutes and every 15 minutes thereafter for 150 minutes. If the substance did not retard feeding the molasses was soon consumed. Sometimes the better repellents were left in the cage overnight with the starving flies. The amount of the bait consumed by the next morning was a measure of the repellency. The good repellents prevented feeding completely. When large numbers of chemicals were screened for the 1st time they were run at 1 per cent (concentration of the dipping solution) with only one standard for each nine strips. When more accurate comparative tests were made, a standard and the unknown at the same dosage were used in each cage and the tests were replicated several times. This test is capable of detecting small differences and is more precise than most biological procedures.

For the stable fly tests the insects were reared according to the method of Campau *et al.* (1951) and held in 30-inch cubical cages. The method was similar to the official method for house flies and the same media was employed. It has been found, however, that the flat 1-gallon earthen crocks gave more pupae under our conditions than the tall earthen jars. Also the adult flies lived longer when their activity was reduced by diminishing the light. With two large cages the colony

was maintained without interruption. The flies were fed on citrated bovine blood.

Testing the chemicals for repellency against stable flies was done by a method similar to that used for mosquito repellents where the hand, covered with an impregnated fabric, is exposed to the hungry insects. Women's cotton hose, commonly used in the mosquito tests, were not suitable for tests on stable flies. They were discarded in favor of organdy bags having 100 square inches of area. These bags were impregnated by absorbing 6 to 7 ml. of an acetone solution that contained 0.5 gm. of the chemical and hung on a line in the laboratory for about 24 hours. The next day the bags were drawn over the hand and exposed to several thousand hungry stables flies. The time to the first bite was recorded, but if no bites were received in 5 minutes the bags were hung up and tested again the next day. Generally the flies bite in less than a minute if they bite at all. The actions of the flies were also observed and recorded when the better repellents were tested. Some chemicals appear to be attractants.

Not more than about 20 chemicals can be screened with accuracy in one cage under our conditions. Even though the hands were washed after each bag was tested the rapid response first observed gradually diminishes, however, by the next day, the flies have regained their activity.

DISCUSSION OF THE RESULTS AGAINST HOUSE FLIES.—After screening over 500 chemicals on file in this laboratory, it was found that several chemicals were especially effective. The results are given in table 1. The most active were diethyl isocinchomeronate, di-*n*-propyl isocinchomeronate, *tert*-dodecylmercaptopolyoxyethylene and butadiene-furfural copolymer. At a dosage of 5 per cent the poor repellents allowed the bait to be consumed in a few minutes. When no flies are feeding the repellency is obviously good. A comparison of the dosages on the porous papers that can just be tolerated by the flies indicated the relative effectiveness of the repellents.

One high-boiling amine and a pot residue from the distillation of an amine were very effective but the strong odor and dark color of these preclude their use as repellents in most instances. While ethylene thiocyanate shows good effectiveness in these tests it was found to lose its effectiveness rapidly and, furthermore, it is too irritating for use as a repellent.

Since the diethyl and di-*n*-propyl esters of isocinchomeronic acid are excellent repellents, other esters were tried. The di-*n*-butyl was about as good as the diethyl but the methyl and isopropyl esters have substantially no repellency. Since isocinchomeronic acid is pyridine-2,5-dicarboxylic acid, the next to be considered were esters of isomeric acids, having the carboxyl groups in different positions on the pyridine ring. Esters of the acids with the carboxyl groups in the -2,3-, -2,4-, and -2,6- positions were also tested. The dimethyl esters of all these have substantially no repellency. A comparison of the diethyl esters of all four acids show the repellency declines in the following order: the -2,5-, the -2,4-, the -2,6-, and the -2,3-. The di-*n*-propyl esters decline in effectiveness in same order.

After finding that butadiene-furfural copolymer was a good fly repellent, several derivatives were made.[2] The aldehyde group was reduced to the alcohol, the double bonds were hydrogenated, chlorine and bromine were added and methyl groups were added. These compounds are all repellent but none is more active than the parent compound when tested against houseflies.

The mercaptopolyoxyethylenes vary somewhat in effectiveness. The alkyl group of the mercaptan has been varied from 4 to 16 carbon atoms and the number of ethylene oxides from 1 to 16 with some exceptions. Compounds containing one ethylene oxide are without repellency.

In miscellaneous tests some of these repellents have also been applied to the windows of a Peet Grady chamber where flies ordinarily like to congregate. The glass was given a light spray of a 2 per cent solution in acetone. House flies were introduced immediately and once each week for 4 weeks. The diethyl and di-*n*-propyl isocinchomeronates were more than 90 per cent repellent after 4 weeks. Also several tests have been made using *tert*-dodecylmercaptopolyoxyethylene on screen doors. The repellent was applied *per se* by swabbing. Screens so treated were repellent for at least 2 months.

[2] These derivatives were prepared by J. C. Hillyer and coworkers of the Phillips Petroleum Company.

Table 2.—The repellency of some chemicals to the stable fly as determined by the organdy bag method.

No.	Name	Seconds to First Bite After Aging Bags			Behavior of Flies 2nd Day
		2 Days	3 Days	4 Days	
11	Butadiene-furfural copolymer	NB[1]	30	—	avoid
14	High-boiling amine mixture	NB	NB	42	hit, leave
49	Diethyl isocinchomeronate	25	—	—	crawl
326	Di-*n*-propyl isocinchomeronate	NB	NB	182	hit, leave
484	*tert*-Dodecylmercaptopolyoxyethylene	125	—	—	crawl and leave
247	Ethylene thiocyanate	13	—	—	—
178	High-boiling amine residue	NB	NB	243	avoid

[1] No bites in 5 minutes.

DISCUSSION OF RESULTS AGAINST STABLE FLIES.—Some of the repellents listed in table 1 have been tested by the organdy bag method against hungry stable flies. The results are shown in table 2. None of the repellents were very good after 72 hours. Stable flies were much harder to repel than house flies. The mode of action is probably different. With house flies there must be a taste factor where bait is involved but with biting flies the repellent on the fabric should not impart a taste to the victim's blood. Odor has some influence when the repellent is completely avoided but in most instances the flies continuously alight and leave.

Toxicity.—None of the chemicals showing promise as repellents have enough toxicity to insects to be of value as insecticides. Some kill is obtained with di-*n*-propyl isocinchomeronate when flies are confined with it at high dosages. The skin toxicity has been determined in a preliminary way by applying the chemicals to a clipped portion of a rabbit. Very little effect was obtained with the mercaptopolyoxyethylenes and with butadiene-furfural copolymer. Di-*n*-propyl isocinchomeronate caused some irritation but no systemic poisoning. Diethyl isocinchomeronate showed considerable toxicity to rabbits. Even though there was a reaction with some of these chemicals on rabbits, no signs of toxicity could be detected when used on calves at practical dosages.

SUMMARY.—Since flies are becoming resistant to many formerly effective insecticides, repellents as a method of control are being considered. Over 500 chemicals were tested against house flies and four chemicals were found that gave a high repellent action. These are diethyl isocinchomeronate, di-*n*-propyl isocinchomeronate, mercaptopolyoxyethylenes, and butadiene-furfural copolymer. The repellents showing the most activity against house flies were then tested against stable flies on organdy bags drawn over the hand. The most effective compound was di-*n*-propyl isocinchomeronate. The mercaptopolyoxyethylenes and butadiene-furfural copolymer were good repellents.

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Some Observations on the Use of Isoparaffin Oils As Carriers for Agricultural Chemicals[1]

LYLE D. GOODHUE

Liquid carriers for agricultural chemicals generally are limited to water or water emulsions of certain oils, especially where plants are involved. Only within the last few years have certain isoparaffin fractions of very low phytotoxicity been available and as yet little use has been made of them as carriers. Isoparaffins are characterized by their low odor, low toxicity to plants, their ability to spread on leaf surfaces and their apparently lower toxicity to animals than similar hydrocarbons in the same boiling range.

Crafts (1946) first found that certain isoparaffin fractions were low in phytotoxicity. Some information on isoparaffins was given by Griffiths & Janes (1950)[2] regarding the low toxicity to plants and the insecticidal action of some fractions. Crawford & Jaquier (1951) show certain fractions of isoparaffins to act synergistically with several insecticides. In this paper results of tests are given which indicate the possible use of specific isoparaffin fractions as carriers for certain agricultural chemicals.

DESCRIPTIONS OF THE ISOPARAFFINS USED.—The isoparaffin petroleum fractions essentially are a complex mixture of saturated branched chain paraffin hydrocarbons, and useful as insecticide base oils. Two fractions were used in this study, one in the boiling range of 361 to 400°F., *Soltrol*[3] *140*, and a higher fraction boiling from 402 to 481, *Soltrol*[3] *180*. These fractions contained no more than a trace of olefins, naphthenes or aromatics and probably only small amounts of normal paraffins. The typical inspection data are given in table 1.

SPREADING PROPERTIES.—One physical property of these isoparaffin fractions worthy of special mention is their spreading ability on leaf surfaces. In the course of cotton defoliation tests it was discovered that the *Soltrols* would spontaneously spread on cotton leaves to give a very thin film while other oils such as diesel fuel and fuel oil did not spread. Several oils approximating the listed distillation ranges were also tested to determine their ability to spread on cotton leaves. It was found that cetane, a long chain normal paraffin, does not spread but that mixtures of it and isoparaffins spread approximately in proportion to the amount of isoparaffins in the mixture.

In order to measure more accurately the difference in spreading ability, laboratory tests were made on several oils normally employed as pesticide carriers. A comparison of the area of spread of several oils on test plants with their surface tensions and viscosities is shown in table 2. The surface tensions of the oils that spread most are the lowest but the difference is

Table 1.—Inspection data for the isoparaffin fractions, *Soltrol*[1] *140* and *Soltrol*[1] *180*.

PHYSICAL OR CHEMICAL PROPERTY	TEST RESULTS	
	Soltrol 140	*Soltrol 180*
Distillation		
IBP °F.	361	402
10%	367	423
20%	368	428
50%	372	441
70%	374	450
90%	382	464
95%	389	470
EP	400	481
Specific gravity, at 20/4° C.	0.7595	0.7813
API gravity, at 20/4° C.	54.8	49.6
Density of liquid, at 20/4° C.	6.3	6.5
Refractive index, at 20° C.	1.4247	1.4355
Viscosity at 100° F., Centistokes	1.541	2.20
Bromine number	0.44	0.62
Kauri butanol number	25.90	24.67
Aniline number, °F.	185	198
Comparative spot dry time, minutes	54	150
Unsulfonated residue, %	97	98
Odor, residual	None	None
Odor, osmoscope	0	0
Flash, TCC, °F., 760 mm.	141	181
Fire, COC, °F.	165	205
Total sulfur, weight %	0.0022	0.0048
Color, Sybolt	+30	+30

[1] Registered trade mark, Phillips Petroleum Company.

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[1] Contribution from Phillips Petroleum Company, Bartlesville, Oklahoma.

[2] Griffiths, A. E., and M. J. Janes. "A Phytoxicity and Insecticidal Study of a Petroleum Isoparaffin Fraction." Presented before a joint symposium on the agricultural applications of petroleum products at the meeting of the American Chemical Society, Chicago, Illinois, September 3–8, 1950.

[3] Registered trade mark, Phillips Petroleum Company.

Table 2.—The spreading of some oils on cotton, kalanchöe and beans, compared with the surface tensions and viscosities.

THE OIL	DROP WEIGHT, MG.	AREA OF SPREAD, SQ. IN.			SURFACE TENSION DYNES/CM.	VISCOSITY CENTISTOKES
		Cotton	Kalanchöe	Bean		
Soltrol 140	3.1	1.25	1.49	.40	26.3	1.61
Soltrol 180	3.9	.90	1.24	.59	27.5	2.20
No. 1 fuel oil	3.8	.02	.03	.12	28.9	1.70
Diesel fuel	3.7	.02	.02	.03	30.7	3.04
Aromatic oil	2.5	.02	.08	.03	32.4	1.74

not great. The spreading on beans is less because the pubescence requires some oil to cover it.

If surface tension is a factor surface active agents might cause non-spreading oils to spread. *Tween 80* or *Triton X100* did not cause diesel fuel to spread.

Phytotoxicity Tests.—Aromatics and olefins are generally considered to be the most toxic of the hydrocarbons while iso- and normal paraffins are the least toxic to either plants or animals. Based on our tests with *Soltrol 140*, we have known for several years that such isoparaffins have almost no toxicity to plants. This has been confirmed by other workers in the field. The results of tests made under our greenhouse conditions on the toxicity of *Soltrol 180* to 14 species of economic plants are shown in table 3 and compared with the indicated phytotoxicity of diesel fuel. The effect of dormant spray oil, deodorized kerosene, kerosene and white mineral oil on some of the species of plants is also indicated. All the oils were applied by spraying until run-off. Readings on the injury to the plants were taken after 1, 2, 7, and 14 days. Since there is not room to report all of these data in the table the most significant one, the 7-day reading, was used.

STABILITY OF ISOPARAFFINS.—Under certain conditions and because of the tertiary carbon atoms, isoparaffins are subject to oxidation with the formation of peroxides and/or hydroperoxides. This can increase the phytotoxicity of the isoparaffins but it is not a very serious objection because formation of peroxidic materials occurs only in sunlight and can be reduced by the addition of inhibitors. Under the usual storage conditions there appears to be no peroxide or hydroperoxidic formation. A drum of *Soltrol 140* stored in the open showed no peroxides or hydroperoxides after 5 years and was without phytotoxicity. Some phytotoxicity tests were made on *Soltrol 180* exposed to sunlight for 6 weeks. The peroxide content expressed as hydrogen peroxide reached 0.0094 and there was some increase in plant injury to lettuce and in addition sorghum was affected. Some tests were also made where different amounts of prepared *Soltrol hydroperoxide* were added. All species of plants were injured when the peroxide content was above 0.04 per cent.

SOLUBILITY OF PESTICIDES.—These isoparaffins because of their complete saturation are only fair solvents for some of the pesticides. Oily materials are more soluble while most crystalline compounds are less soluble. The solubilities of some materials are shown in table 4. Pure pyrethrins are soluble in all proportions but polymers and waxes are insoluble. This indicates that this type of oil might be used as a selective solvent for the extraction of pyrethrum from the flowers to obtain a more refined extract. Since technical parathion was used in these tests the undissolved material when the concentration is above 5 per cent may be impurities.

Table 3.—A comparison of the phytotoxicity of *Soltrol 180* and five other common oils.

PLANT SPECIES	PHYTOTOXICITY RATING[1]					
	Soltrol 180	Diesel Fuel	Dormant Spray Oil	Deodorized Kerosene	Kerosene	White Mineral Oil
Beans	1	6	10	7	10	5
Peas	1	6	10	3	10	7
Tomatoes	1	6	10	10	10	3
Lettuce	2	3	10	10	10	5
Sorghum	1	6	10	10	10	10
Cucumbers	1	—	10	10	6	2
Cotton	1	5	6	7	7	5
White clover	1	8				
Peanuts	1	1				
Radishes	1	5				
Wheat	1	5				
Mustard	1	3				
Sunflowers	1	3				
Squash	1	8				

[1] The ratings of phytotoxicity run from 1 indicating no apparent injury to 10 where all or nearly all the plants are killed.

Also the tars in impure chlorodane are insoluble which suggests a means of purifying this insecticide. The solubility characteristics are similar to *Freon 12*.

Table 4.—Approximate solubilities of some pesticides in *Soltrol 180* expressed as per cent by weight.

PESTICIDE	SOLUBILITY
Aldrin	20 per cent
Dieldrin	4.4 per cent
DDT	5 per cent
Chlordane	Miscible
Lindane	2.1 per cent
Toxaphene	Miscible
Parathion (technical)	5 per cent
Pyrethrum extract	Miscible
Allethrin	Miscible
Piperonyl butoxide	Miscible
2,4-D, isopropyl ester	Slight
2,4,5-T, butyl ester	Slight
tert-Butyl polysulfide (defoliant)	Miscible
N,N-Dimethyl-*tert*-butylthiosulfenyl dithiocarbamate (fungicide)	Miscible

FIELD TESTS.—In order to demonstrate the effectiveness of *Soltrol 180* as a carrier, several cotton insecticides were applied in *Soltrol 180*. To date aldrin, DDT-dieldrin mixture, heptachlor, endrin and toxaphene have been tested.[4] The amount of each insecticide recommended per acre was applied in 2 or 3 gallons of this oil depending on the size of the cotton. All gave a high degree of control. It was noted that some insecticides are more phytotoxic than others when applied in this way. Aldrin and endrin cause no injury while toxaphene exhibited extreme phytotoxicity when applied in this oil.

It appears that the effect of a chemical on a plant is enhanced when applied in *Soltrol*. This can be an advantage for such applications as defoliants or the hormone type of weed killers. Field plot tests on *tert*-butyl polysulfide as a cotton defoliant show this chemical to be about 5 times as effective in *Soltrol 180* as in a water emulsion.

SOLTROLS AS INSECTICIDE BASE OILS.—Crawford & Jacquier (1951) found that pyrethrum, DDT, chlordane, and *Lethane 384* are more toxic to house flies when applied in *Soltrol* than in the best deodorized kerosene. This increased toxicity is attributed to synergism, but also increased insecticidal effectiveness may be a result of the better spreading of the isoparaffin and a more rapid absorption of the insecticide. The peak effectiveness is obtained with *Soltrol 140* and is still good with *Soltrol 180*.

In view of the indicated low mammalian toxicity and other properties, *Soltrol 180* would appear to be well suited as a base oil for a dairy spray. In comparative acute skin toxicity tests it was demonstrated that *Soltrol 180* is much less toxic to rabbits than either kerosene or deodorized kerosene. The clipped trunks of rabbits were painted daily with these three oils. Kerosene and deodorized kerosene killed the animals after four to seven paintings. Those receiving *Soltrol 180* were not systemically affected after 21 paintings. The skin, however, became harder and more wrinkled than normal. One rabbit was dipped in *Soltrol 180* without clipping. This is a very severe treatment but the rabbit lived and gained weight although the skin became hard and wrinkled for a time.

Attention has also been directed to the possible use of isoparaffinic oils as citrus fruit washes or dips for the control of citrus blackfly, scale or other citrus insects.

SUMMARY.—Certain types of isoparaffin fractions boiling in the range of the kerosenes are characterized by their low odor, low phytotoxicity and lower toxicity to animals than ordinary hydrocarbon oils of this boiling range. These oils (*Soltrols*) contain no more than traces of olefins, naphthenes or aromatics and a low percentage of normal paraffins. The ability of these oils to spread on leaf surfaces is unique. On cotton leaves the area covered by a small droplet is about 50 times greater than for an equal volume of diesel fuel or kerosene. The isoparaffins are well adapated as carriers of many pesticides for use on plants and probably as a base oil for dairy cattle sprays. While some oxidation of isoparaffins takes place in the sunlight the process can be inhibited and does not proceed when stored in the usual manner.

[4] These tests were made by Dr. James Dogger formerly of Oklahoma A & M College.

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The Role of Entomology in the Zoology Curriculum

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One may learn from current university catalogs that no course in entomology is offered at many institutions with apparently sound undergraduate programs in zoology. Few if any institutions in the U.S. require a course in entomology for an undergraduate degree in zoology. When one reads such a surprising catalog statement as "general entomology may be counted for major credit" (in zoology), it must be concluded that entomology is being neglected in the training of the zoologist.

One reason for this neglect appears to be the failure on the part of deans, committees on curricula, and department heads to recognize the contrast between applied and basic entomology. It is perhaps to be expected that the general public and the college administrators should think of entomology almost entirely in its economic aspects. Applied entomology employs the vast majority of entomologists and administers most of the funds available for entomological work. In the universities it requires specialized courses which utilize expensive equipment. At a Round Table Discussion[1] on the teaching of entomology, the following courses were mentioned as required for the practicing economic entomologist: general entomology; insect taxonomy; insect morphology; insect physiology; economic entomology; apiculture; plant pathology; parasitology; general, qualitative, quantitative, and organic chemistry; general physics; animal husbandry; agricultural engineering, meteorology, statistics.

Applied entomology has become big business. It is a specialized technological field. It seems to bear the same relationship to basic entomology as engineering does to physics. Administrators are no doubt thinking solely of the technological aspects of entomology when they often exclude and never require entomology in their zoology programs. Because of the technological focus some may consider entomology too specialized for the zoology major. Others are possibly concerned with their facilities to offer the array of courses which economic entomologists have suggested and so offer no entomology at all. Because of the focus on economic entomology, it seems that college administrators, zoologists, and even entomologists have forgotten that there is another and more basic aspect of entomology. Basic entomology is concerned with the biology of insects and certain other arthropods. It deals with the morphology, physiology, taxonomy, genetics, ecology, and phylogeny of approximately 80 per cent of all animals. This is not technology but is a fundamental part of zoology which should be included in all zoology programs. Even if entomology is in a separate department, a good course in the biology of insects should be required of all zoology majors.

In contrast with the absence of an entomology requirement in zoology programs one may easily learn that nearly every university requires a course in comparative vertebrate anatomy or comparative vertebrate zoology. Thus some acquaintance with the morphology, classification and phylogeny of the vertebrates is routine for practically all zoologists. There is a need for a similar course requirement with the arthropods as the base. This course, whether it is given in the entomology or in the zoology department should be based on broad biological principles illustrated by the phylum Arthropoda.

Procedures current in general entomology courses are often primarily taxonomic. Three procedures are common: (1) collect and determine everything to family, (2) identification to family of a selected array of forms, (3) species recognition of economically important species. Such procedures contribute little to the training of the zoologist and omit basic biology of the insects. Possibly as a result of the emphasis on taxonomy, students having a course in general entomology or who were even conducting advanced research with insects, have been observed who never have heard of a haemocoel, or knew that a mosquito belonged to the family Culicidae but not that it was an arthropod. These students may know the common insect families but they do not know

PAID PAPER.

[1] Joint meeting of the Sections of Teaching, Amer. Assoc. Econ. Ent. and Ent. Soc. Amer., Cincinnati, Ohio, December 12, 1951.

what any general zoologist should know about the insects.

Since the zoologist is often able to take but one course in entomology this fact must be given consideration. The entomologist can not assume that a number of courses in entomology are required to learn the fundamental biology of the insects. The time limitations of students necessitate that this be accomplished in a single course which will provide the basic foundation for the professional entomologist and which will serve as a terminal course in entomology for the zoologist. This course in the biology of insects should give primary attention to life processes. A special course in physiology is not required to introduce the fundamentals of respiration, circulation, etc. Factors responsible for the biological success of the insects should be discussed at length. The principle of adaptive radiation should be stressed. Certainly here is something unrivaled in other animal groups. The modification of homologous appendages for chewing, walking, digging, swimming, etc., is interesting, is entomology and is zoology.

The interrelations of plants and animals must be studied in field and laboratory. The emphasis should be stronger than a brief closing assignment on pollination and a last minute discussion when final examinations are at hand, giving the student the impression that this is just excess compared with the large number of families he must learn to recognize.

I believe that the major unifying principle of the biological sciences is evolution. The general zoologist is "brought up" on phylogeny. He will expect a similar approach in entomology. A special course in insect phylogeny should not be required to point out general concepts of the relationships of arthropods to the rest of the animal kingdom. The economic importance of insects should not be neglected but only fundamental aspects need to be considered. A biological approach will convince the student that every insect is a part of the great web of life and that its control necessitates a thorough knowledge of the intricacies of the web. The notion that most insects are dangerous and should be destroyed must be dispelled. The following biological concepts are unique or are exceptionally well illustrated by the insects: metamorphosis, polymorphism, social life, instinct, parthenogenesis. These are major principles and require more than a passing mention in connection with family discussions.

There will be objections to these suggestions based on time limitations. However, if teachers of general zoology can cover in one course the broad biological principles illustrated by the entire animal kingdom, certainly the entomologist can do likewise. The general zoologist has departed from the taxonomic approach in the basic course. I believe the entomologist should postpone the family style approach until the advanced courses. A course as general as the one discussed above will be difficult to organize. But by broadening our concepts of basic entomology, by thinking in terms of general biological principles, by considering requirements of the general zoologist, and by a willingness to cast aside the *status quo* it should be possible to offer courses in general entomology that will attract the general zoologist, will become routine for all majors in zoology and will not permit the administrators or the zoology departments to neglect entomology in the zoology curriculum.

An Effective Durable-Type Mothproofing Agent

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Although the sodium salt of N-(3,4-dichlorophenyl)-N′-2 (2 sulfo-4-chlorophenoxy)-5-chlorophenyl-urea, *Mitin*,[3] has been used as a mothproofing agent for the protection of wool and woolen textiles in Europe for several years, it has only been recently that interest in the large scale use of durable mothproofing agents in this country has developed. We wish to summarize available information and present some results obtained in recent years in this laboratory.

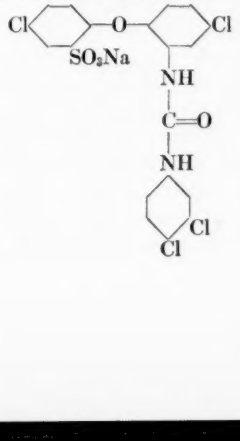
Review of Literature.—Martin, *et al.* (1943) described the synthesis, preparation, chemical and biological properties of *Mitin* together with several related compounds.

Läuger (1944) gives a historical resume of the development of sulfonated mothproofing substances and describes in detail the work leading up to the development of *Mitin*. Chemical properties, including its substantive properties to wool, are described.

Some of the early results of tests with *Mitin* as a mothproofing agent are presented by Wuhrmann (1945, 1946), Snelson (1948), Wälchli (1949), and Burgess (1949). Zinkernagel (1949), in an excellent review with special reference to *Mitin*, brings out the important fact that a compound of this type must not only exhibit the desired entomological properties but also the desired coloristic properties.

Excellent reviews on the general subject of moth-proofing together with descriptions of application and effectiveness of compounds of the "colourless dyestuff" type are given by Moncrieff (1950), Meeuse (1951) and Anon. (1951).

Chemical and Physical Properties.—The active compound is a white, odorless, water soluble powder having the following structural formula:



As might be deduced from the structural formula, the compound has properties similar to many wool dyestuffs. The sulfonic acid group gives the compound substantive properties, and it therefore combines chemically with the wool fiber protein as do other acid wool dyestuffs. The compound may properly be described as a colorless wool dyestuff having insecticidal properties to keratin feeding insects. It is presumed that the compound is released by the digestive action of keratinase on the wool fiber thereby allowing the compound or its toxic breakdown products to be absorbed from the digestive tract.

Mitin has limited water solubility and is soluble only to the extent of about 0.05 per cent in water at room temperature. Since practically all dyebath applications are made at relatively high temperatures 160° to 212° F., solubility at higher temperatures is of more practical interest.

Temperature, °F.	*Solubility g/100 ml.*
160	0.4
180	1.5
212	5.5

In order to improve rate of solubility the product is finely powdered and compounded with a water soluble inert. The commercial product "*Mitin* FF Conc." contains 42.5 per cent active ingredient.

Application.—Since *Mitin* draws completely from the dyebath onto the wool, dosages are expressed in terms of per cent of the weight of the wool. Two pounds of the product dissolved in a bath in which 100 pounds of wool are to be treated results in a dosage of 2 per cent of the weight of the wool after drying. The product is first dissolved in hot or boiling water (1 lb. to 10 quarts) to make sure of complete solubility and then added to the bath followed by thorough agitation before introducing the goods to be treated. *Mitin*-treated wool cannot be distinguished from untreated wool on the basis of handle, appearance, color, odor, softness, etc. It is compatible with most dyestuffs and auxiliary agents used in acid-

[1] Technical Director.
[2] Entomologist.
[3] Reg. U. S. Pat. Off.

dyeing of wool. It may be applied in the dyebath or as a separate "after-treatment."

Although *Mitin* draws slowly and nearly completely in a neutral bath, it gives best results from the standpoint of both exhaustion and fastness when applied in an acid bath. Maximum fastness is obtained when applied in an acid bath at or near the boil for 30 to 60 minutes. Formic, acetic and sulphuric acids (1 to 2 per cent) may be used to acidify the bath. At lower temperatures (160 to 180° F.) and in neutral or near-neutral baths, the time of treatment should be increased to allow for complete exhaustion and fixation.

TEST METHODS.—Test methods used are those recently adopted as tentative methods, by the Chemical Specialties Manufacturers Association (Anon. 1952a) and the American Association of Textile Chemists and Colorists (Anon. 1952b) and which agree in substance with the quantitative methods originally described by Heal (1942). Rearing methods for test insects are those described in the publications cited above. Standard Botany test flannel was used in all cases unless otherwise specified. All dosages are expressed in terms of per cent on the weight of the dry wool. Deviations as to age and number of larvae, length of test period, use of baits, etc. are noted in the tables. Work in this laboratory has been limited to the webbing clothes moth, *Tineola biselliella* (Hum.); black carpet beetle, *Attagenus piceus* (Oliv.); and furniture carpet beetle, *Anthrenus vorax* (Waterh.). Thousands of tests have been made during the past few years and only typical results can be presented in this paper.

Table 1.—Dosage-mortality data, webbing clothes moth larvae.

Per Cent *Mitin* FF Conc.	Age of Larvae (Days)	Per Cent Mortality (Days)			
		7	14	21	28
0.5%	7	20	50	70	78
	14	0	4	26	36
	25	5	14	20	21
1.0%	7	100	—	—	—
	14	90	100	—	—
	25	45	81	100	—
1.5%	7	100	—	—	—
	14	100	—	—	—
	25	63	94	100	—
2.0%	7	100	—	—	—
	14	100	—	—	—
	25	90	100	—	—

RESULTS.—*Webbing Clothes Moth.*—*Mitin*, when applied to the wool fiber, is highly toxic to webbing clothes moth larvae even in low dosages. The high rate of mortality of larvae at different stages of growth is shown in table 1.

Results of a weight loss test by the Tentative Standard Method (Anon. 1952a; Anon. 1952b) are shown in table 2.

Table 2.—Weight loss test with webbing clothes moth larvae. (Eight replicates of ten larvae each.)

Treatment	Average Mg. Wt. Loss	Per Cent Mortality 7 Days	Per Cent Mortality 14 Days
Two per cent *Mitin* FF Conc.	2.2	90	100
Untreated	86.9	0	0

In a more vigorous test using 25 larvae per replicate and using test flannel swatches which have been "baited" with a 30 per cent water suspension of debittered Brewer's yeast, the results shown in table 3 were obtained.

Table 3.—Baiting test with webbing clothes moth larvae. (Four replicates of 25 larvae each.)

Treatment	Average Mg. Wt. Loss	Per Cent Mortality (Days) 3	7	10	14
2 per cent *Mitin* FF Conc.	3.1	66	93	99	100
Untreated	103.0	4	5	5	5

Our data and observations confirmed those recently reported in some detail by Lothmar (1951) that *Mitin* acts definitely as a stomach poison and not as a repellent. Other tests carried on in this laboratory using both treated and untreated test flannel in the same test container have all given negative results in so far as repellency is concerned.

It is apparent from these data that *Mitin* is extremely effective against webbing clothes moth larvae. This has been confirmed by hundreds of tests using commercially treated woolen fabrics a few examples of which are shown in table 4.

Black Carpet Beetle.—The effect of *Mitin* on different ages of black carpet beetle larvae is shown in table 5.

Table 4.—Results of commercial applications.

TYPE OF MATERIAL	PER CENT *Mitin* FF CONC. BY CHEMICAL ANALYSIS	AV. MG. WT. LOSS	PER CENT MORTALITY	
			7 Days	14 Days
Carpet	—[1]	3.1	90	100
Yarns	—	2.8	100	100
Coating	—	2.7	100	100
Wool cloth	1.3	1.7	85	100
Flannel	2.0	2.2	90	100
High pile fabric	1.9	5.1	85	100
Low pile fabric	2.0	2.5	86	100
Felt	1.8	2.2	40	95
Felt	—	2.6	83	98

[1] 2 per cent applied in all cases but not analyzed chemically except as noted.

It is observed that young larvae are readily killed but that older larvae are more slowly affected, and in fact the observed effect on older larvae is somewhat like that of a repellent. This repellency is observed, however, only after an initial period of feeding and this combined with the toxicity to young larvae indicates that this apparent repellency is due to a poisoning effect on the larvae.

Results obtained from tests on different types of fabrics are shown in table 6.

Furniture Carpet Beetle.—We have done considerable work with this species as it shows certain advantages as a test insect over the black carpet beetle larvae. It has a shorter life cycle and it can be reared on the same medium (wool plus Brewer's yeast) as the webbing clothes moth. Wälchli & Zinkernagel (1952) have discussed the use of this species as a test insect.

Comparative feeding tests with the furniture carpet beetle larvae have been made and are shown in tables 7 and 8. Results with the 6-week-old larvae in table 7 for a 2-week test are in good

Table 5.—Dosage mortality data, black carpet beetle larvae.

PER CENT *Mitin* FF CONC.	AGE OF LARVAE (WKS.)	PER CENT MORTALITY (DAYS)				AV. MG. EXCREMENT
		7	14	21	28	
0.625	4	19	84	98	100	0.7
	8	5	5	10	70	3.9
	12	0	0	0	0	9.4
	16	0	0	0	0	10.7
1.25	4	63	100	—	—	0.6
	8	15	30	35	75	1.6
	12	0	0	0	0	5.5
	16	0	0	0	0	5.1
2.5	4	79	100	—	—	0.7
	8	5	25	40	95	1.6
	12	0	0	0	0	3.8
	16	0	0	0	0	3.2
Untreated	4	5	5	8	8	3.6
	8	0	0	0	0	19.0
	12	0	0	0	0	25.3
	16	0	0	0	0	17.8

Table 6.—Results of commercial applications.

TYPE OF MATERIAL	PER CENT *Mitin* FF CONC. BY CHEMICAL ANALYSIS	AV. MG. EXCREMENT WT.	
		14 Days	28 Days
Carpet	1.6	4.0	5.1
Knit Goods	2.0	1.8	1.9
Cashmere	1.8	3.3	4.4
Yarn	1.7	2.7	3.2
Fabric	2.2	3.4	3.8
Coating	1.9	3.8	4.6
Serge	2.5	1.9	2.6
Socks	1.4	1.9	2.1
Felt	1.9	2.5	2.8
Yarn	2.2	1.6	1.7

Table 7.—Feeding of furniture carpet beetle larvae on *Mitin*- treated flannel.

PER CENT *Mitin* FF CONC.	AGE IN WEEKS	MG. EXCREMENT (14 DAYS)
0.625	4	2.1
	6	6.4
	8	4.3
1.25	4	1.0
	6	4.2
	8	2.0
2.5	4	1.4
	6	3.1
	8	1.6
Untreated	4	14.6
	6	45.8
	8	27.4

Table 8.—Results of commercial applications.

TYPE OF MATERIAL	PER CENT *Mitin* FF CONC. CHEMICAL ANALYSIS	AV. MG. EXCREMENT	
		BCB[2]	FCB[3]
		4 Week Tests	
Cashmere	2.0	3.5	3.5
Flannel	1.8[1]	4.5	2.4
Yarn	—	3.7	2.3
		2-Week Tests	
Mohair	—	2.3	1.7
Cashmere	—	2.2	1.9
Camel's Hair	—	3.9	1.8
Blanket	—	2.3	3.1

[1] 2 per cent *Mitin* FF Conc. applied but chemical analysis not made except as indicated.
[2] Black carpet beetle.
[3] Furniture carpet beetle.

agreement with the data for 12-week-old black carpet beetle larvae in table 5. In addition comparisons of the black carpet beetle and furniture carpet beetle have been made on commercially treated fabrics and these data are shown in table 8 indicating that the two species show a similar degree of feeding on *Mitin*-treated material and the same criteria of effectiveness may be used.

Fastness.—The criterion of effectiveness of a durable moth-proofing agent is its ability to withstand various treatments such as washing, dry cleaning, etc.

Table 9.—Fastness of *Mitin* to standard test flannel (2% application).

Treatment	Black Carpet Beetle Av. Mg. Excrement (4 Weeks)	Webbing Clothes Moth Per Cent Mortality (2 Weeks)
Dry Cleaned 30 times	3.2	100
Original	4.4	100
Blank	42.3	0
Washed 25 times (Maytag Machine)	5.1	100
Washed 5 times (Launderometer)	5.2	100
Washed 25 times	6.4	95
Original	4.6	100
Blank	40.0	0

that may be encountered during the use of the fabric or garment. Procedures used in the tests referred to below are those described in the American Association of Textile Chemists and Colorists Yearbook (Anon. 1952b) and in CS59-44 (U. S. Department of Commerce) (Anon. 1944). Typical data are presented in table 9.

The dry cleaning results are typical of those usually encountered. The action of the dry cleaning solvent tends to render wool less palatable to the larvae. The wash tests indicate that five washings by the American Association of Textile Chemists and Colorists Launderometer method are equal to 25 washings by an automatic home washer.

Table 10 gives data on three commercially treated fabrics that have been in storage for 5 to 6 years in our laboratory and represent recent tests (October 1952) on the remaining portions of the same swatches originally sent in for test immediately after treatment. These samples are still satisfactorily mothproofed.

Table 10.—Effectiveness of *Mitin* treatments after 5 years of storage.

Treatment	Black Carpet Beetle Av. Mg. Excrement (2 Weeks)	Webbing Clothes Moth Per Cent Mortality (2 Weeks)
Flannel (Treated Aug. 1946)	4.2	95
Camel's Hair (Treated May 1947) Unbleached	3.7	100
Camel's Hair (Treated May 1947) Bleached	4.5	100

SUMMARY.—The sodium salt of N-(3,4-dichlorophenyl)-N′-2(2-sulfo-4-chlorophenoxy)-5-chlorophenyl-urea sold commercially as *Mitin* FF Conc. (42.5 per cent active ingredient) is an effective and durable mothproofing agent. It may be described as a colorless dyestuff having insecticidal properties to keratin feeding insects. Its chemical, physical and fastness properties are described. Data showing its effectiveness against larvae of the webbing clothes moth, black carpet beetle and furniture carpet beetle are presented.

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The Western Corn Rootworm, *Diabrotica virgifera* Lec. in Kansas[1]

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The western corn rootworm, *Diabrotica virgifera* Lec. is a comparatively recent pest of the growing corn plant in Kansas. The first report of injury in the state was made to the Norton County agricultural agent by a grower in the summer of 1945. The species was not identified in 1945 but subsequent observations have substantiated the accuracy of reports that the western corn rootworm was the species involved. This species has also been designated as the New Mexico and Colorado corn rootworm.

Gillette (1912) had this insect called to his attention in 1909 by a neighbor who reported, "that his sweet corn was being killed by a little grub boring in the roots." Later in the season, beetles were observed resting on the leaves of the corn plants and were thought to be the adults of the larvae which had fed upon the roots. The injury caused by the larvae was so severe that few plants escaped the attack.

During the summer of 1910, at least one-third of the plants in one field of sweet corn in the vicinity of Loveland, Colorado, were reported killed. The damage was observed to be greater in fields where corn followed corn year after year.

Corn growing in the vicinity of Fort Collins showed less injury during the summer of 1911. Gillette also observed that the beetles occurred in two definite color patterns, one of which resembled closely the markings of the striped cucumber beetles, *Diabrotica vittata* (Fab.).

Beetles exhibiting the other pattern were darker in color, without definite stripes but with a yellow spot on the tip of each elytron. The striped beetles had been described by LeConte (1868) as *Diabrotica virgifera* while Horn (1893) described the darker ones as *Diabrotica filicornis*.

Professor Wickham, of the University of Iowa, to whom Gillette had sent the beetles for identification, based his determination upon the description of the species given by LeConte and Horn. He stated further that *Diabrotica virgifera* Lec. was known to occur in New Mexico, Arizona, and Sonora (Mexico), while *Diabrotica filicornis* Horn was known in New Mexico. Gillette observed that beetles with striped, uniformly dark, and intergrading color patterns occurred in cornfields in about equal numbers.

Gillette conducted no morphological studies to determine the sexes but observed that the striped beetles deposited eggs while the dark ones did not. He also stated that the two forms were frequently found in copula. He concluded that the dark individuals were males while the striped ones were females. The observations by the writers concerning the habits

[1] Contribution No. 608 Department of Entomology. Studies conducted at the Kansas Agricultural Experiment Station under Hatch Project 289 and Hatch 284.
[2] Associate Professor, Professor, and Instructor, respectively.

of the beetles in the field do not substantiate those made by Gillette since there is a gradual intergrading of color patterns.

OCCURRENCE IN KANSAS.—Robert Dole, a student from Norton County, while attending Kansas State College in 1948, was the first to call the writers' attention to rootworm injury to corn by this species when he brought in four dead beetles and injured corn stalks for identification and examination in the spring of that year. During the summer of the same year, he collected and sent in 22 beetles, all of which were dark in color. On August 6, the writers conducted a survey in several counties along the northern border of the state to determine distribution, extent of injury, habits of the beetles and the larvae, as well as seasonal activities of the species.

Since this survey was conducted when the beetles could be found in the cornfield, their occurrence as well as injury caused by the larvae were taken as criteria for the study of distribution. Farms on which larval injury occurred also revealed the presence of a large number of beetles, active on silks, leaves, and tassels of corn plants.

Surveys to determine distribution of the western corn rootworm were made on a number of occasions, but to date the survey has not consisted of a complete coverage of all counties. Beetles were collected in Norton, Phillips, Smith, and Osborne counties in 1948. In 1949, correspondence reports were received from Rawlins, Decatur, Jewell, Republic, and Cloud counties. During the same year, beetles were collected in Scott and Finney counties. The reports from Jewell, Republic, and Cloud counties were authenticated by a rather extensive survey in 1952. No stage of the western corn rootworm was found in Nemaha, Pottawatomie, or Wabuansee counties in 1952; hence, this marks the known eastern boundary of present distribution in Kansas.

The western corn rootworm had been a pest of corn in the southern tier of counties in Nebraska (Tate & Bare 1946) prior to reports of injury from the northern counties in Kansas. While no surveys have been conducted to determine the distribution of the species in the western Kansas counties, it probably is present there because it occurs in the eastern counties of Colorado.

The severest root damage caused by the larvae, and the greatest number of beetles, were observed in cornfields which had been planted to corn continuously for several years. One severely damaged field had been planted to corn successively for 15 years. Corn grown in fields which had been cropped with oats, wheat, soybeans, or sorghums or had been fallowed the previous season showed no rootworm injury even though adjacent to badly infested fields. The beetles also were less numerous in such fields, indicating that the beetles did not fly long distances from the fields in which they spend their larval stages.

INJURY BY THE LARVAE.—The larval feeding period has been found to extend from the middle of June until the latter part of July. The period apparently varies with the season, the soil conditions and other environmental factors because larvae were present in some fields while in others the species was in the pupal stage. The larval feeding period usually coincides with the time at which field corn normally makes its most rapid growth. Where larval concentrations were high, all the main roots and rootlets were tunnelled or cut off as shown in figure 1 (center). Often, the roots and bases of the stalks were so badly damaged that decay organisms gained entrance and completely destroyed the roots.

The larvae began feeding upon the roots when the plants were small and continued until the larvae changed to pupae. Farmers stated that in heavily infested fields, the slender white larvae were conspicuous in the upturned soil during cultivation. Injury to the stalks was less evident when the soil was well supplied with moisture but as soon as the soil became dry, many stalks died. A considerable number of stalks were dwarfed, especially when all the roots were destroyed as shown in figure 1 (center). Often both the main roots and brace roots touching the soil were completely destroyed. Where infestations were heavy, the bases of the stalks were so severely tunnelled that the burrows extended into the center of the stalk. Figure 1 center shows the base of one stalk which had the roots destroyed. Many roots were completely severed. Stalks damaged to this extent offered no resistance when an attempt was made to pull them from the soil, and lodged readily

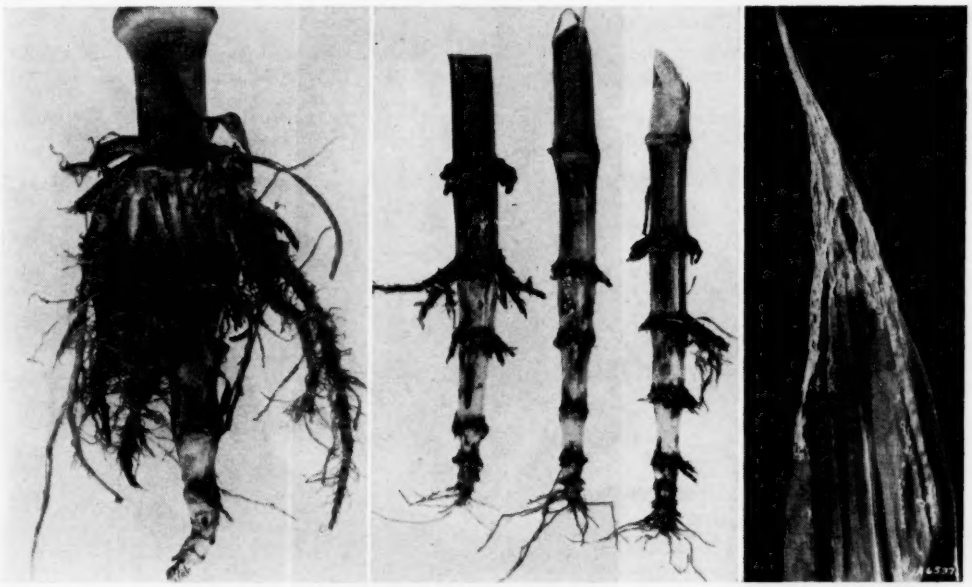

FIG. 1.—Severe corn rootworm injury to young growing corn plant. *Left:* Normal corn roots slightly damaged by rootworms. *Center:* Bases of stalks with roots severely injured by the larvae of *Diabrotica virgifera*. *Right:* Leaf of corn plant severely injured by beetles.

during a wind or rain storm.

Ears produced on stalks which had fallen were difficult to harvest and were subjected to further loss due to attack by birds, rodents, and decay organisms. Many plants, in badly infested fields, failed to produce ears and there was considerable variation in the sizes and the weights of the ears, when present. Many ears were chaffy in appearance and bore badly shrivelled kernels. Hot dry weather during the latter part of August hastened the maturity of the plants in damaged fields while those in un-infested areas retained their green color. Occasionally, a stalk was found which had lodged with one or more brace roots in contact with the soil which had produced a mass of new fibrous roots. These were stimulated to grow following heavy rains which came after the rootworms had destroyed the main roots and after the feeding period of the larvae was over. Severely injured stalks showed considerable wilting during the heat of the day. Severe root injury gave the plants the appearance of early maturity when actually they were immature. Later in August, areas of dead stalks appeared while adjoining areas with less injury maintained a green appearance.

HABITS OF THE BEETLES.—Not all the injury to the plants was caused by the larvae. The beetles fed upon every part of the growing corn plant above ground. Figure 1 (right) shows typical leaf injury caused by adult feeding. The beetles congregated in the whorl, in axils of the leaves, on the tassels, and on the ears. It was estimated that 125 beetles often were present in the whorl when the tassel was emerging. They were extremely active and, when disturbed, flew rapidly from weeds or stalks on which they were resting. They also tended to run and hide quickly on the underside of leaves or on the side of the stalk opposite the observer. The beetles congregated in the tassels where they fed on the pollen grains but did no damage to the tassel. These bent over tassels partially emerged from the whorl furnished the adults protection from the hot sun, rain and other adverse weather conditions.

Considerable numbers of beetles were observed in newly emerging silks. Where the beetles were abundant, all the silks were severed closely at the tips of the ears (Fig. 2, right). Where the clipping had been done as the ears began to silk, incomplete fertilization of the ovules occurred and resulted in ears sparsely covered with kernels as shown in figure 2 (center).

Frequently, injury to the ear was not

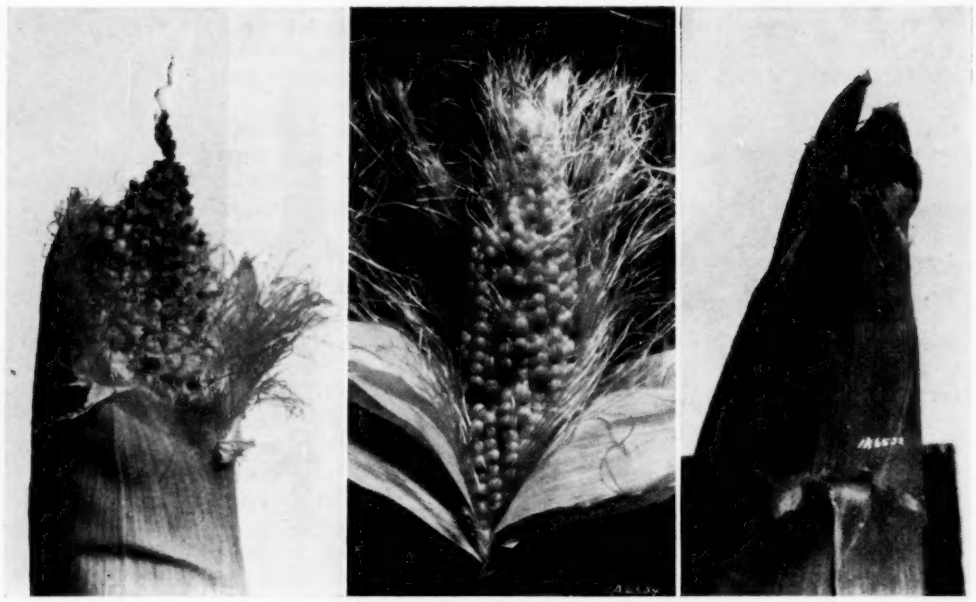

FIG. 2.—Injury to ears due to beetles feeding upon the silks and developing kernels. *Right:* Tips of ears with silks closely severed by the beetles. *Center:* Sparsely filled ear as a result of beetles clipping the silks prior to fertilization. *Left:* Damage to kernels due to adult feeding at the tip of the ear.

confined to the destruction of the silks, but the well formed kernels at the tips of the ear were fed upon for a distance of two inches posterior to the tip of the ear (Fig. 2, left). This condition kept the tip of the ear exposed to weather, to entrance of fungi, and to attacks by other insects and birds. When beetles were abundant in the fields, they fed upon the tender leaves in the whorls of the corn plants and upon the tips of the leaves. Small holes were eaten through the tender leaves while the tips and edges of the mature leaves were skeletonized. The damaged edges of the mature leaves "rolled" toward the mid-rib. This type of injury should be classified as of minor importance.

It was observed that sorghums although in many cases adjacent to heavily infested fields of corn, showed no injury by this species.

SUMMARY. The western corn rootworm, *Diabrotica virgifera* Lec., was first reported causing injury in Kansas in 1945 in Norton County. Since that time, reports from a number of counties indicate an eastward movement of this species. No stage of the western corn rootworm was found in Nemaha, Pottawatomie, and Wabaunsee counties in 1952; hence, this marks the known eastern boundary of present distribution in Kansas.

The severest root damage caused by the larvae, and the greatest number of beetles, were observed in cornfields which had been planted to corn successively for 15 years. The larval feeding period was found to extend from the middle of June until the latter part of July. This period apparently varied with the season, the soil conditions, and other environmental factors. Often both main roots and brace roots touching the soil were completely destroyed. Where infestations were heavy, the bases of the stalks became so severely tunneled that the burrows extended into the center of the stalk.

The beetles were found feeding upon every part of the growing corn plant above ground. It was estimated that as many as 125 beetles often were present in the whorl when the tassel was emerging. Although considerable injury occurred on leaves of corn, the outstanding injury resulted from clipping of the silks. Where the beetles were abundant, all the silks were severed closely at the tips of the ears. When the clipping was done as the ears began to silk, incomplete fertilization of the ovules occurred and resulted in ears sparsely covered with kernels.

Sorghums, although in many cases adjacent to heavily infested fields of corn, showed no injury by this species.

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Effect of Molecular Configuration on Relative Toxicity to House Flies as Demonstrated with the Four *Trans* Isomers of Allethrin

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In 1950 chemists in the Bureau of Entomology and Plant Quarantine separated allethrin (*dl*-allethrolone acylated with a mixture of *cis* and *trans dl*-chrysanthemumic acids) into the *cis* and *trans* fractions and the latter fraction into its two racemic pairs of stereoisomers (Schechter *et al.* 1951). Gersdorff & Mitlin (1952) determined the relative toxicity of these materials to the house fly, *Musca domestica* L., by the turntable method, and found that molecular configuration was important in regard to insecticidal action. They also discussed evidence of the importance of configuration on the relative toxicity of other pyrethroids. It therefore seemed desirable to obtain precise information on the relative toxicity of the eight possible stereoisomers in allethrin. In 1953 such a study was made possible when the same chemists resolved *dl*-allethrolone and prepared the four isomers formed by esterification of *d*- and *l*-*trans* chrysanthemumic acids with the two keto alcohols (LaForge *et al.* 1953). This paper reports the results of this study and their significance with respect to molecular configuration.

MATERIALS.—The preparation and physical characteristics of these four stereoisomers are described by LaForge *et al.* (1953). In this paper they will be designated as the *l-d*, *d-l*, *l-l*, and *d-d* *trans*-allethrin, the first symbol in each pair referring to the optical activity of the allethrolone component of the molecule and the second to that of the acid component. The samples used were of a high degree of purity. A distilled sample of allethrin, analyzing 95 per cent by the hydrogenolysis method, was used as a standard of comparison. As an additional check a mixture of the four isomers in equal proportion was included in the study.

PROCEDURE.—The materials were dissolved in refined kerosene and diluted with the same solvent to form sprays for each at four or five concentrations selected according to preliminary toxicity tests.

Knockdown and mortality of house flies were determined in tests with these sprays by the Campbell turntable method. Eight replications were made, all sprays being tested simultaneously on eight populations of flies. Approximately 95 flies were used in each test. The average age of flies in each population was 2 to 3 days.

To evaluate relative toxicity and determine the precision of the estimates, the mortality data were subjected to probit analysis as described by Finney (1952).

MORTALITY AND KNOCKDOWN.—The mortality and knockdown data are summarized in table 1.

Although knockdown, as a measure of initial paralysis, is a toxic action, in this paper the terms "toxic" and "toxicity" are reserved to refer solely, as is usual in bioassays of insecticides, to lethal action.

It is apparent, from comparison of the concentrations causing approximately the same range of mortalities, that the isomers differ greatly in both toxicity and knockdown value. The *d-d* ester is the most effective, being of the order of 4 times as toxic as allethrin and giving greater knockdown in about the same

Table 1.—Mortality and knockdown of house flies caused by the *trans* stereoisomers of allethrin, their equiproportional mixture, and allethrin. All values are the means of eight replications.

MATERIAL	CONCENTRATION	KNOCKDOWN	MORTALITY
	Mg. per ml.	*Per Cent*	*Per Cent*
l-d Compound	2	100	92.0
	1	100	60.8
	0.5	99.4	27.3
	.25	95	9.8
d-l Compound	8	100	91.7
	4	99.8	52.8
	2	96	25.1
	1	67	12.9
l-l Compound	64	99.4	98.4
	32	98	69.1
	16	90	33.9
	8	41	15.8
d-d Compound	0.5	100	93.7
	.25	100	77.7
	.125	99.7	47.5
	.0625	99.1	16.6
	.0313	74	8.2
Mixture	2	100	97.8
	1	100	91.5
	0.5	100	69.2
	.25	99.7	25.2
	.125	92	11.6
Allethrin	2	100	96.7
	1	100	87.0
	0.5	100	44.5
	.25	99.0	16.2

ratio. The *l-d* ester is somewhat less toxic than allethrin and is also somewhat less effective in causing knockdown. The *d-l* ester is close to one-fourth as toxic as the *l-d* ester but lower than this ratio in knockdown effectiveness. The *l-l* ester is by far the least toxic of the four, being less than one-hundredth as toxic as the most effective, the *d-d* ester; the ratio of knockdown effectiveness is much lower. The prepared mixture is a little more effective than allethrin in both toxic and knockdown action.

Thus, from table 1, it may be seen that the decreasing order of effectiveness in both toxic and knockdown action is the *d-d* ester, allethrin, the *l-d* ester, the *d-l* ester, and the *l-l* ester. The decrease is relatively greater for knockdown, especially in the last two esters; that is, the change to the *l* form in the acid component is accompanied by appreciably greater losses in knockdown effectiveness than in toxicity.

EVALUATION OF RELATIVE TOXICITY.—Provisional graphical lines were fitted on the assumption that the data could be represented by parallel lines and the individual, statistically fitted, regression lines determined. The slopes of the latter, with their calculated standard errors, for the materials in the order in which they appear in table 1 were 2.96 ± 0.24, 2.70 ± 0.16, 3.05 ± 0.15, 2.47 ± 0.24, 2.91 ± 0.24, and 3.27 ± 0.25 probits per unit log concentration. It was concluded that the hypothesis of parallelism was justified. Therefore a generalization procedure was followed, in which the lines were fitted statistically to a common slope, 2.87 ± 0.13. Analysis of chi-squares showed that heterogeneity between populations of flies had to be allowed for by multiplying all variances by a heterogeneity factor, 15.14.

The generalized equations for the lines showing the regression of mortality, expressed in probits, on concentration in milligrams per deciliter, expressed as logarithms, are as follows:

l-d Ester	$Y=2.871X-0.3954$
d-l Ester	$Y=2.871X-2.1839$
l-l Ester	$Y=2.871X-4.4527$
d-d Ester	$Y=2.871X+1.7993$
Mixture	$Y=2.871X+0.5281$
Allethrin	$Y=2.871X+0.1162$

From these equations the median lethal concentrations (LC 50's) were calculated. Relative toxicity was calculated as the inverse ratio of LC 50's. The estimations together with their standard errors are given in table 2.

DISCUSSION.—The two racemic pairs of these isomers would be the equiproportional mixtures of the *l-d* and *d-l* esters and of the *d-d* and *l-l* esters. They are the unidentified pairs previously separated from allethrin and designated *α-dl-trans* (crystalline allethrin isomer) and *β-dl-trans* isomers (Schechter *et al.* 1951). The relative toxicity to house flies of these pairs was estimated by the turntable method, and the *β-dl-trans* pair was about 5 times as toxic as the *α-dl-trans* pair (Gersdorff and Mitlin 1952). The ratios of toxicity in table 2 serve to identify these pairs. The *α-dl-trans* pair is the mixture of the *l-d* and *d-l* esters and the *β-dl-trans* pair is the mixture of the *d-d* and *l-l* esters.

The *d-d* ester is identified as the isomer that was predicted to be, if separated, the most toxic pyrethroid known—about 10 times as toxic as natural pyrethrins (Gersdorff & Mitlin 1952).

It seems highly probable that in mix-

Table 2.—Relative toxicity of the *trans* stereoisomers of allethrin, their equiproportional mixture, and allethrin.

MATERIAL	LC 50	TOXICITY RELATIVE TO ALLETHRIN	
		Original Basis	*dl-trans* Fraction Basis
	Mg. per dl.		
trans-Allethrin isomers:			
l-d	75.7± 6.2	0.663 ±0.078	0.579 ±0.049
d-l	318 ± 26	0.158 ±0.019	0.138 ±0.012
l-l	1959 ±161	0.0256±0.0030	0.0224±0.0019
d-d	13.0± 1.1	3.857 ±0.45	3.367 ±0.28
Allethrin:			
Original basis	50.2± 4.2	1.00 ±0.12	0.873 ±0.104
dl-trans fraction basis	43.9± 3.7[2]	1.15 ±0.14[2]	1.00 ±0.031[1]
dl-trans Mixtures:			
Equiproportional—			
Found	36.1± 2.9	1.39 ±0.16	1.21 ±0.10
Calculated	42.7	1.18	1.03
dl-trans Fraction—[3]			
Found	—	—	1.334 ±0.042[1]
Calculated	32.9	1.528	1.334

[1] From previous study (Gersdorff and Mitlin 1952).
[2] Calculated from *dl-trans* fraction basis.
[3] Containing 27 per cent α- and 73 per cent β-*dl trans* isomer

tures of such like chemical structure as these stereoisomers joint action will be of the similar type. Nevertheless, until more is known about synergism and also about antagonism the possibility of the existence of these types of action should not be ignored and, when possible, information should be sought by means of inclusion in the study of at least one mixture. This is one reason for including the equiproportional mixture in this series of tests. The observed mortalities of this mixture are much greater than would be expected for independent action.

It was shown previously (Gersdorff & Mitlin 1952) that no synergism or antagonism existed in two mixtures of different proportions of *cis* and *trans* fractions of allethrin. It was assumed that the joint action in mixtures of α-*dl-trans* and β-*dl-trans* isomers was of the similar type, since no mixtures of them could be tested in that study. That such mixtures are of this type will appear through experimental, albeit indirect, means when relationships determined in the present study are compared with those of the earlier bioassay.

To find out whether there is a significant departure from similar action in the mixture of the four stereoisomers in the present study, the toxicity of the mixture may be compared with the toxicity expected for that type of action on the basis of equivalents either to one of the components, the usual procedure, or to allethrin, since the last equivalents have already been determined (table 2). The expected toxicity for similar action is calculated as the sum of the equivalents of the components of the mixture. On the allethrin basis, the substituted equation is

$$0.25\times0.663+0.25\times0.158+0.25\times0.0256+0.25\times3.857=1.176.$$

On either basis the same ratio to the expected will be obtained, 1.184, which is the quotient of the fraction 0.1302/0.1100 (from the basis on *d-d* equivalents) as well as that of 1.392/1.176 (from the basis on allethrin equivalents). Since tests of significance are properly made on the log-concentration scale, the log of this ratio, 0.0734, is compared with the minimum log ratio required to demonstrate synergism or antagonism, ±0.0991. Since this requirement has not been met and since the possibility of a mutually masking action is highly improbable, it must be concluded that the four stereoisomers are acting similarly in the mixture.

Study of these ratios among themselves and in connection with previous work indicates that they are all slightly high, and that the relative toxicity of allethrin may be slightly underestimated. For example, the equiproportional mixture, containing less β-*dl-trans* isomer, according to the bioassay, than the sample of the *dl-trans* fraction tested previously (Gersdorff &

Mitlin 1952), should be less toxic than that fraction. That is, although the experimental error is high enough to permit overlapping here, the ratio (found to be 1.392) should be lower than 1.334. To adjust for this apparent underestimation and to make relationships with previous work more readily apparent without reference to standard errors, these ratios may be referred to allethrin through a different base. Such a base may make use of the relation between the ratio of 1.334 for the relative toxicity of the *dl-trans* fraction found previously and the ratio for that fraction as may be calculated by means of the ratios found for the stereoisomers in this study and the proportions of *α-* and *β-dl-trans* isomers in that fraction.

It is logical to do this for other reasons. First, ratios of toxicity have been found to be reproducible by this method, especially for such similar toxicants as these pyrethroids, even though the populations of house flies may be markedly heterogeneous. Second, the precision of the LC 50 estimations was much greater in the earlier study than in the present one, the relative standard errors for the LC 50 of allethrin being 2.19 per cent and, because of heterogeneity between populations of flies, 8.44 per cent. Third, in the study determining the ratio 1.334, pyrethrins was used as a second standard of comparison and the ratio of toxicity of allethrin to pyrethrins was 3.06, close to the mean of many estimations of this parameter. What this procedure does, then, is to express toxicities relative to a better estimation for allethrin. Fourth, this procedure uses a base dependent on assays with four materials rather than one.

The reference of the ratios to this base may be achieved in the following manner. The ratio of toxicity of the *dl-trans* fraction—that is, its allethrin equivalent—is calculated as the sum of the equivalents of its components as determined from the ratios for the stereoisomers in the proper proportions. According to the bioassay, 27 per cent of the sample of the *dl-trans* fraction used consisted of the *α-dl-trans* isomer and 73 per cent the *β-dl-trans* isomer (Gersdorff & Mitlin 1952). The equation is therefore as follows:

$$0.27R_\alpha + 0.73R_\beta = R_f$$

in which R_α, R_β, and R_f are the respective toxicity ratios of the *α-dl-trans* and *β-dl-trans* isomers and the *dl-trans* fraction. Since the first is the *l-d* plus *d-l* pair and the second the *l-l* plus *d-d* pair, the substituted equation becomes

$$0.135\times0.663+0.135\times0.158+0.365\times0.026+0.365\times3.857=1.528.$$

The ratios as given on the original basis in table 2 may now be referred to the base 1.334 by simply multiplying them by the factor 0.873, obtained by dividing 1.334 by 1.528. As may be seen, the effect of this procedure on the ratios will be the same as would occur if the assumption had been made that the relative toxicity of allethrin had been underestimated in the present study by one standard error. The ratios on the new base are given in the last column of table 2. It is apparent that they all are well within experimental error of the values obtained on the original basis. How well the adjusted ratios check with all previously determined estimations may now be readily seen, if use is made of the fact that, when joint action is of the similar type, the sum of the equivalents of the components of a mixture equals the equivalent of the mixture. The method of calculation and the comparisons are made in table 3.

Table 3.—Comparison of calculated toxicity ratios for equiproportional mixtures of allethrin *trans* stereoisomers with reported values.

Mixture	Calculation	Toxicity Ratio	
		Calculated	Found
l-d and *d-l*	0.5×0.579+0.5×0.138	0.359	0.354[1]
d-d and *l-l*	0.5×3.367+0.5×0.0224	1.69	1.69[1]
d-d and *l-d*	0.5×3.367+0.5×0.579	1.97	2.04[1]
d-l and *l-l*	0.5×0.138+0.5×0.0224	0.080	0.04[2]

[1] Gersdorff and Mitlin 1952.
[2] LaForge *et al.* 1952

The ratio of toxicity of allethrin, which should now be unity, may be calculated from these estimations for the *trans* compounds and the previous estimations for the toxicity and proportion of the mixture of *cis* compounds, as follows:

$$0.31(0.365\times3.367+0.365\times0.0224+0.135\times0.579+0.135\times0.138)+0.69\times0.854=1.00.$$

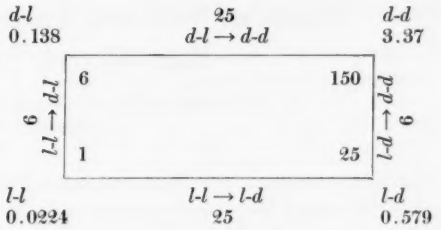
It is obvious that the parameters are especially well estimated in this way, when compared with the allethrin base of the

earlier study. The good agreement in the estimations for the *α-* and *β-dl-trans* isomers shows that practically the same ratios would have been obtained if reference had been made through the data for either of these pairs rather than for all four isomers. The factors in these procedures would have been 0.861 (0.354/0.411) and 0.868 (1.685/1.941).

The earlier testing work with the *l-trans* acid ester of *dl*-allethrolone, made on the small amounts of material then available and with purity of the preparation unestablished, showed its relative toxicity to be very low. The present work shows it to be slightly more toxic, and most of its toxicity is ascribed to the *d-l* compound. This is consistent with the very interesting pattern into which the relative toxicities fall. If the proper ratios are compared (and this will hold true, of course, whichever base is selected), the following will be obtained:

$$d\text{-}d/d\text{-}l = 24.4$$
$$l\text{-}d/l\text{-}l = 25.8$$
$$d\text{-}d/l\text{-}d = 5.82$$
$$d\text{-}l/l\text{-}l = 6.16$$
$$d\text{-}d/l\text{-}l = 150$$

Two generalizations may therefore be made. With the same acid component the change from the *l* to the *d* form of the allethrolone component is accompanied by a 6-fold increase in toxicity of the ester. With the same allethrolone component the change from the *l* to the *d* form of the acid component is accompanied by a 25-fold increase in toxicity of the ester. Corollarily, the change in each component simultaneously from the *l* to the *d* form is accompanied by the product of the separate effects. The pattern may be simply illustrated by the diagram (right, above). Each side of the rectangle represents the relative effect accompanying a change in configuration in one component, the arrows pointing in the direction of increasing effect. The relative effect accompanying changes in both components is equal to the product or division of the single effects.



SUMMARY.—The relative toxicity to house flies, *Musca domestica* L., of the four *trans* stereoisomers of allethrin in comparison with allethrin was evaluated by the Campbell turntable method.

The *l*-allethrolone *d-trans* chrysanthemumic acid ester, the *d-l* ester, the *l-l* ester and the *d-d* ester are, respectively, 0.58, 0.14, 0.022, and 3.4 as toxic as allethrin.

Two generalizations were made. With the same acid component the change from the *l* to the *d* form of the allethrolone component is accompanied by a 6-fold increase in toxicity of the ester. With the same allethrolone component the change from the *l* to the *d* form of the acid component is accompanied by a 25-fold increase in toxicity of the ester.

The change in each component simultaneously from the *l* to the *d* form is accompanied by the product of the separate effects.

All the stereoisomers cause high knockdown of flies at the concentrations required to cause high mortality.

The decreasing order of effectiveness in both knockdown action and toxicity is the *d*-allethrolone *d*-chrysanthemumic acid ester, the *l-d* ester, the *d-l* ester, and the *l-l* ester. The decrease is greater for knockdown, especially in the last two esters; that is, the change to the *l* form in the acid component is accompanied by appreciably greater losses in knockdown effectiveness than in toxicity.

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Tests of Selected Insecticides Against Resistant Salt-Marsh Mosquito Larvae[1,2]

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Recent research on the chemical control of larvae of the salt-marsh mosquitoes *Aedes taeniorhynchus* (Wied.) and *A. sollicitans* (Wlkr.) under Florida conditions was largely limited to DDT until 1949. Laboratory and field tests against larvae of *Anopheles quadrimaculatus* Say had been conducted with other chlorinated hydrocarbon insecticides as they became available, but most of them were inferior to DDT and were therefore not considered worthy of large-scale field evaluation. No further consideration was given to these or newer materials until the discovery in 1949 that salt-marsh mosquitoes had developed resistance to DDT in certain areas (Deonier & Gilbert 1950; Deonier *et al.* 1950; Keller & McDuffie 1951).

This discovery of DDT resistance in salt-marsh mosquitoes brought about a renewed interest in the less effective chlorinated hydrocarbon insecticides, as well as in several phosphorus compounds that had been considered too toxic to man for practical use. During the last three seasons (1950–52) most of the available materials of these types have been evaluated in the laboratory and field against resistant larvae in an effort to find an effective substitute for DDT. All the laboratory test data in this paper were obtained in 1952, but the field test data are the accumulation of all 3 years.

Larvae for laboratory tests were obtained from salt marshes in two areas in Brevard County, Florida. One of them (Cocoa Beach) had been intensively treated with DDT from 1945 to 1949 and with BHC from 1950 to 1952, and larval and adult resistance to DDT was considered to be exceptionally high. The other area (Titusville-Shiloh) had been subjected to occasional treatments with DDT for several years and with BHC since 1950, and the larvae were considered moderately resistant. Field tests were also conducted in these two areas, often against the same brood of larvae used in the laboratory tests.

METHODS.—Larvae for laboratory tests were collected when they were in the late third or early fourth instar and carefully transported approximately 50 miles to the laboratory. The test procedure consisted of exposing 25 larvae in beakers containing 250 ml. of acetone-water (distilled) suspensions of the toxicants. Duplicate tests were run with each insecticide at concentrations ranging from 0.05 to 0.0005 p.p.m. Mortality counts were taken after 24 and 48 hours of exposure at 70° F.

Small-plot field tests were run on breeding marshes in ponds and pools ranging in size from 100 to 7,000 square feet. The insecticides were applied in emulsions with a small hand atomizer at the uniform rate of 5 pints per acre, the concentration of the toxicant being varied to give dosages ranging from 0.1 to 0.0025 pound per acre.

Practical-scale spray tests were made on plots ranging in size from 40 to 70 acres. The sprays were applied by a Stearman airplane equipped with underwing spray booms. The plane was flown at a speed of 80 m.p.h. at an altitude of about 75 feet, which gave an effective swath of about 125 feet. The insecticides were applied in both emulsions and oil solutions at the rate of 3 quarts per acre, the concentration of toxicant being varied to give the desired dosage. In both types of tests the effectiveness of the treatments was based on the difference in dipping counts before and 24 hours after treatment.

RESULTS.—*Laboratory Tests.*—The results of the laboratory tests are presented in table 1.

EPN was the most effective material tested, and was somewhat more toxic than dieldrin, heptachlor, aldrin, and parathion. Lindane and toxaphene were less toxic, but more effective than DDT, malathon, and tetrapropyl dithiopyrophosphate. All the insecticides were less effective against the larvae from the intensively treated area than against those from the occasionally treated areas, but

[1] This work was conducted at the Orlando, Fla., laboratory of the Bureau of Entomology and Plant Quarantine under funds allotted to the Bureau by the Department of the Army.

[2] Presented at the meeting of the Cotton States Branch of the Entomological Society of America in New Orleans, La., February 9–11, 1953.

Table 1.—Relative toxicity of various insecticides against larvae of resistant salt-marsh mosquitoes in laboratory tests. (Average of 2 to 4 replications.)

Insecticide	Per Cent Mortality in 48 Hours After Treatment with Indicated P.P.M. Concentration						
	0.05	0.025	0.01	0.005	0.0025	0.001	0.0005
Larvae from Occasionally Treated Marshes							
EPN	—	100	100	100	100	76	51
Dieldrin	—	100	100	95	71	59	—
Heptachlor	—	100	100	96	61	54	—
Parathion	—	100	100	93	54	22	—
Aldrin	—	100	99	87	68	53	—
Lindane	—	100	98	69	59	42	—
Toxaphene	—	100	89	64	56	38	—
Chlordane	—	100	81	39	28	24	—
DDT	100	92	66	62	45	—	—
Malathion	100	66	37	34	37	—	—
Tetrapropyl dithio-pyrophosphate	94	74	54	47	41	—	—
Larvae from Intensively Treated Marshes							
EPN	—	100	100	100	62	34	—
Dieldrin	—	100	90	34	16	8	—
Heptachlor	—	100	100	84	24	—	—
Aldrin	—	100	82	26	18	16	—
Lindane	—	72	36	34	26	16	—
Toxaphene	—	—	98	50	30	24	—
DDT	78	56	38	34	24	—	—
Malathion	52	40	32	30	22	—	—
Tetrapropyl dithio-pyrophosphate	42	26	12	6	0	—	—

the order of toxicity was the same for both areas except in the case of lindane and toxaphene.

Small-Plot Field Tests.—The results of tests conducted in the intensively treated area (Cocoa Beach) against mixed populations of *Aedes taeniorhynchus* and *A. sollicitans* larvae are given in table 2.

EPN and parathion were the most effective insecticides, both giving nearly perfect control at 0.01 pound per acre. Heptachlor and dieldrin were only slightly less effective. Lindane and chlordane gave 100 per cent control at 0.05 pound per acre. DDT and malathion were effective at 0.05 and 0.1 pound per acre, but TEPP and tetrapropyl dithiopyrophosphate were relatively ineffective at these dosages.

Table 2.—Results of small-plot field tests with emulsions of various insecticides against fourth-instar larvae of *Aedes taeniorhynchus* and *A. sollicitans*. (Average of two replications.)

Insecticide	Per Cent Reduction in 24 Hours After Treatment with Indicated Dosage in Pounds per Acre					
	0.1	0.05	0.025	0.01	0.005	0.0025
EPN	—	100	100	99	91	71
Parathion	—	100	100	100	73	73
Hepatchlor	—	100	100	92	23	—
Dieldrin	—	100	100	93	—	—
Lindane	—	100	89	65	—	—
Chlordane	100	100	69	0	—	—
DDT	100	90	71	21	—	—
Malathion	95	98	6	—	—	—
TEPP	49	0	0	—	—	—
Tetrapropyl dithio-pyrophosphate	12	19	0	—	—	—

Practical-Scale Tests.—Results of the aerial applications are given in table 3.

In the occasionally treated area applications of 0.1 pound of lindane, dieldrin, and heptachlor and 0.4 pound per acre of chlordane gave nearly complete control of mixed populations of larvae. Lindane at 0.05 pound, and toxaphene, chlordane, and DDT at 0.2 pound per acre, gave close to 90 per cent reductions. Aldrin at 0.1 pound per acre showed only 69 per cent control, and a similar dosage of chlordane was relatively ineffective.

In two tests in the intensively treated area aldrin at 0.2 pound per acre was ineffective against *Aedes sollicitans* larvae, and DDT at 0.4 pound per acre was only 77 per cent effective against a mixed larval population.

SUMMARY.—Selected insecticides were tested in the laboratory and in the field against larvae of resistant salt-marsh mosquitoes, *Aedes taeniorhynchus* (Wied.) and *A. sollicitans* (Wlkr.)

In laboratory tests salt-marsh mosquito larvae from an intensively treated

Table 3.—Results of aerial spray tests with different insecticides for the control of larvae of the salt-marsh mosquitoes *Aedes sollicitans* and *A. taeniorhynchus*.

LOCATION	INSECTICIDE (IN OIL UNLESS OTHERWISE INDICATED)	DOSAGE (POUND PER ACRE)	PRE-TREATMENT COUNT PER DIP	PER CENT REDUCTION 24 HOURS AFTER TREATMENT
	Intensively Treated Area			
Cocoa Beach	DDT	0.4	264	77
	Aldrin	.2	576	0
	Occasionally Treated Area			
Titusville	Lindane	0.1	500	99
	Lindane	.05	83	91
	Lindane	.025	500	83
	Lindane emulsion	.05	60	90
	Lindane	.025	374	89
	Heptachlor	.1	431	99
	Heptachlor emulsion	.1	357	99
	Aldrin	.1	29	69
Shiloh	Chlordane	.4	23	99
	Chlordane	.2	322	92
	Chlordane	.1	85	29
	Dieldrin	.1	138	97
	Toxaphene	.2	500	92
	DDT	.2	306	89

area in Brevard County, Florida, were less susceptible to EPN, heptachlor, dieldrin, aldrin, lindane, toxaphene, DDT, malathion, and tetrapropyl dithiopyrophosphate than larvae from an occasionally treated area in the same county. EPN, parathion, heptachlor, and dieldrin were the most effective of the insecticides tested.

In small-plot field tests EPN and parathion were the most effective insecticides against resistant larvae. Heptachlor and dieldrin were about equal in effectiveness and were more toxic than lindane, chlordane, DDT, and malathion. TEPP and tetrapropyl dithiopyrophosphate were relatively ineffective.

In practical-scale field tests lindane, heptachlor, and dieldrin were the most effective insecticides in the occasionally treated area, followed by chlordane, toxaphene, DDT, and aldrin. DDT and aldrin gave poor results against larvae in the intensively treated area.

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Narrow-Cut Petroleum Fractions of Naphthenic and Paraffinic Composition for Control of California Red Scale[1]

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Failure to obtain satisfactory control of the California red scale, *Aonidiella aurantii* (Mask.), by fumigation with HCN was first reported about 1912 (Quayle 1941, p. 489). The use of petroleum oil spray was a possible alternative, but the oils available had often caused damage to the trees in the form of extensive "foliage burn" (dead leaf tissue).

In 1915–16, Gray & deOng (1926) showed that the hydrocarbons which could be removed from petroleum oil by treatment with sulfuric acid were the ones largely responsible for "foliage burn." However, the increased cost of acid-refined oil limited its use because the stable emulsions of that day made it necessary to use a high concentration of oil in the spray mixture. The quick-breaking emulsion principle developed by deOng *et al.* (1927) made it possible to obtain oil deposits adequate for pest control with relatively low concentrations of oil in the spray mixture. This overcame the obstacle of cost in the use of acid-refined oils, *i.e.*, oils with a high unsulfonated residue (Cox 1943).

After this development, Smith (1932) began intensive studies of factors involved in the use of oil sprays to control California red scale and other pests of citrus in southern California. In part, he found that insecticidal efficiency and deleterious effect on the trees were closely related to the so-called "weight" of the spray oil (that is, the molecular size as indicated by the distillation range), and that this provided a better basis for classification of spray oils than viscosity.

An excellent discussion by Ebeling (1950, pp. 175–9) of evidence from laboratory and field experiments with the various California grades of petroleum spray oils (Erb 1932; Marshall 1932) shows that greater efficiency in the control of California red scale is obtained with increases in the "weight." This increase in efficiency accrues not only from a higher percentage kill of scale insects present at the time the spray is applied, but, of more importance, from an increase in the effect of the residual oil deposit against scale crawlers emerging from surviving scale. Increase in the molecular weight provides higher mortality and greater insecticidal activity for a longer interval.

About 1939, Chapman *et al.* (1943) and Pearce *et al.* (1942) began investigations of the relation between chemical composition and insecticidal efficiency of various dormant and foliage spray oils against several common insect pests of deciduous trees. They concluded that an oil which is highly paraffinic in character is the most desirable type. Recently, Riehl & LaDue (1952) reported that the results of laboratory studies indicated that the insecticidal efficiency of spray oils against insects and mites attacking citrus may be considerably improved by proper selection with respect to structural character and molecular size.

Results of experiments to investigate the relation of chemical composition and physical properties to the insecticical efficiency of two series of petroleum fractions against California red scale on orange trees in the field are reported in this paper.

Experimental Oils.—The two oil stocks selected for fractionation represented distinctly naphthenic and paraffinic types, and were the same as those used by Pearce & Chapman (1952) to prepare narrow-cut fractions for laboratory studies of the insecticidal efficiency of petroleum structures against eggs of the oriental fruit moth, *Grapholitha molesta* (Busck). These workers supplied samples of these fractions to the University of California Citrus Experiment Station for the lab-

[1] Paper No. 778, University of California Citrus Experiment Station, Riverside, California.

[2] The writers wish to express their appreciation to the Shell Oil Company for supplying the narrow-cut petroleum fractions for these investigations, and for the determination of their physical and chemical properties; to the Socony-Vacuum Oil Company, Inc., for the supply of paraffin base oils 1 and 2 and the determination of their properties; to the citrus growers who granted the use of their orchards for experimental plots; to J. P. LaDue, J. L. Pappas, J. L. Rodriguez, and G. F. Wood, of the Department of Entomology of the University of California Citrus Experiment Station, and to F. E. Cook, formerly of this department, for valuable assistance in the course of the work.

Table 1.—Important physical characteristics of the various experimental oils used.[1]

Oil	Molecular Weight[2] a	Molecular Weight[2] b	Viscosity Saybolt, Sec. at 100° F.	API Gravity, 60° F.	Distillation Temperature, °F. 10%	50%	90%	Per Cent Distilled at 636° F.	Unsulfonated Residue, Per Cent
California spray-blending stock (naphthenic)	302	295	79.2	28.9	610	645	692	40	96.2
Fraction 1	242	220	44.1	30.7	536	550	565	100	98.6
Fraction 2	267	267	52.7	30.7	580	588	594	100	98.0
Fraction 3	276	279	62.3	29.7	606	610	616	100	96.0
Fraction 4	290	295	70.7	29.4	622	628	633	95	95.2
Fraction 5	297	306	79.5	29.4	638	642	647	7	94.6
Fraction 6	314	323	93.7	29.2	655	659	664	0	93.8
Fraction 7	318	336	111.6	28.4	668	675	682	0	93.6
Fraction 8	340	352	136.1	28.3	686	692	698	0	92.8
Residue 9	361	400	225.0	27.7	710	730	756	0	92.0
Carnation divider oil (paraffinic)	330	326	68.1	36.8	631	682	727	13	99.0
Fraction 1	246	245	41.2	41.8	547	568	586	100	99.0
Fraction 2	290	270	46.8	39.8	604	612	619	100	99.0
Fraction 3	299	290	51.3	38.9	633	640	646	25	98.8
Fraction 4	303	308	60.4	37.4	655	663	668	0	99.0
Fraction 5	349	329	69.2	36.6	676	687	694	0	98.2
Residue 6 (cracking noted)	404	394	124.6	33.9	700	730	752	0	95.0
Paraffin base 1		316	59.0	36.7	624	655	700	20	94.0
Paraffin base 2		332	102.5	32.0	662	694	cracked	0	92.0
Paraffin base 3		334	80.0	39.1	656	698	cracked	0	89.0
Paraffin base 4		359	115.0	31.3	700	cracked	—	0	88.0
California spray oil (naphthenic)[3]									
Light-medium		292	67.5	29.3	571	618	682	65	92.0
Medium		297	75.7	28.9	590	632	687	53	92.0

[1] Properties, except those for molecular weight by viscosity correlations and for paraffin base oils 1 and 2, determined by laboratories of the Shell Oil Company and Shell Development Company.
[2] Molecular weight determined (a) ebullioscopically in benzene and (b) by viscosity correlations of Mills *et al.* (1946).
[3] California Department of Agriculture classification (Erb 1932; Marshall 1932).

oratory studies cited above (Riehl & La-Due 1952), against California red scale and citrus red mite. Data on the Engler boiling characteristics, physical properties, and ring analysis of these two oil stocks, and narrow-cut (approximately 10 per cent) fractions of each, are presented by Pearce & Chapman (1952).

Narrow-cut fractions of these two oils in sufficient amounts for field tests against citrus pests were provided by the Shell Oil Company. These fractions were cut to 11.1 per cent of the stock, except for Carnation divider oil pot residue, fraction 6, which was 45.5 per cent of the stock. The stocks of the oils and the respective fractions were water-white—*i.e.*, unsaturates had been removed by exhaustive treatment with sulfuric acid or its equivalent.

Important physical characteristics of the oils used in the experiments are summarized in table 1.

PROCEDURE.—Unless specifically noted otherwise, the petroleum oils used in these field experiments were prepared as dilute aqueous emulsions by the tank-mixture method (Smith 1932), using 4 ounces of blood albumin spreader per 100 gallons of spray mixture.

Conventional orchard spray equipment utilizing a high-pressure reciprocating-type pump operating at 550 pounds pressure was used in applying the finished sprays. The apertures of the discs used in the single-nozzle spray guns were 8/64 inch in diameter. To insure thorough coverage, the sprays were applied manually both inside and outside the tree from the ground, and additionally to the outside of the tree from the catwalk of a hydraulic spray tower.

In all tests, applications were made during periods when air temperatures were below, and relative humidities were above, the levels which accumulated experience in the individual test areas has shown to be safe for the application of petroleum oils to citrus trees.

Groves were selected for these studies with regard both to uniformity of trees in size, shape, and general vigor, and to the generally high density of the California red scale populations.

The tests conducted in Canoga Park and Riverside in 1948 were based on unreplicated plots of 8 trees each. In the Canoga Park test the experimental block was 4 rows wide and 55 trees long; in the Riverside test the experimental block was 10 rows by 20 rows in extent. In the test conducted in Riverside in 1950, individual

Table 2.—Relative efficiency of various narrow-cut petroleum fractions of naphthenic and paraffinic composition for control of California red scale on orange trees in two locations, as indicated by number of adult females within the same fruit maturity cycle (3 or 6 months) and on the succeeding cycle of fruit (12 months).

Oil	Scales per Fruit on—						
	Valencia Orange Trees (Canoga Park) Sprayed 9/23/48			Navel Orange Trees (Riverside) Sprayed 10/11/48			
	Pretreatment 9/23/48	Posttreatment 3/22/49	Posttreatment 9/8/49	Pretreatment 10/11/48	Posttreatment 12/29/48	Posttreatment 11/14/49	C.R.I.,[1] 12/29/48
	Concentrations, 4 Quarts/100 Gallons						
California spray-blending stock (naphthenic)	0.7	0.0+	0.2	14.7	0.7	3.3	122
Fraction 1	0.3	0.0	0.0+	13.9	7.4	7.9	1366
Fraction 2	0.3	0.0	0.2	17.3	3.1	6.6	460
Fraction 3	0.0+	0.0	0.0	8.4	0.6	11.4	183
Fraction 4	0.4	0.0+	0.6	16.9	1.1	10.1	167
Fraction 5	0.6	0.0+	0.2	6.9	0.2	1.5	74
Fraction 6	0.2	0.0	0.0+	10.5	0.2	0.7	49
Fraction 7	—	—	—	8.9	0.4	1.3	115
Carnation divider oil (paraffinic)	0.3	0.0	0.0	17.7	0.5	2.3	72
Fraction 1	1.2	0.2	3.3	7.1	0.5	1.6	181
Fraction 2	0.7	0.0	0.5	8.8	0.5	3.0	146
Fraction 3	0.3	0.0	0.3	18.2	0.8	3.7	113
Fraction 4	0.7	0.0	0.0	20.4	0.7	1.3	88
Fraction 5	1.1	0.0	0.0+	20.4	0.3	1.3	38
Paraffin base 1	0.2	0.0	0.0+	27.3	1.0	4.6	94
	Concentration, 7 Quarts/100 Gallons						
California spray oil (naphthenic)[2]							
Light-medium	0.3	0.0	0.0	15.2	0.6	4.8	101
Medium	0.6	0.0	0.0+	7.7	0.3	5.4	100

[1] Corrected relative infestation (Ebeling 1947); 100 = results with medium-grade oil at a concentration of 7 qts./100 gal. of spray mixture.
[2] California Department of Agriculture classification (Erb 1932, Marshall 1932).

plots consisted of one pair of trees for each treatment, replicated 3 times. The test area in this orchard was 15 by 18 rows.

Pretreatment and posttreatment populations of California red scale were determined by counting the number of live adult female scales on 40 fruits selected at random from the peripheral area of each tree, in a zone 3 to 6 feet from the ground. Counts were made without removing the fruits from the trees, previous studies by Ebeling and Persing (Ebeling 1947) having shown that an adequate estimate of California red scale populations could be made by examining 30 to 40 fruits in this manner. In the experimental block established in Riverside in 1950, live adult female scales were also counted on each of 40 mature leaves selected at random from the previously described peripheral portion of each tree.

RESULTS.—Results obtained in the experimental blocks established at Canoga Park on Valencia orange trees and at Riverside on navel orange trees in 1948 are presented in table 2. In these experiments the efficiency of various narrow-cut petroleum fractions used at a concentration of 4 quarts per 100 gallons of spray mixture was compared with that of standard treatments with California light-medium-grade and medium-grade spray oils used at a concentration of 7 quarts per 100 gallons.

In the experiment conducted on navel orange trees at Riverside in 1950, the narrow-cut fractions were used at two concentration levels, 2 and 4 quarts per 100 gallons of spray mixture. The insecticidal efficiency of these oils was compared with that of California medium-grade oil used at a concentration of 4 quarts per 100 gallons. The conventional dosage for citrus pest control of 7 quarts per 100 gallons was also used in the series of treatments with California light-medium-grade and medium-grade spray oils. The data obtained are presented in table 3. The values

Table 3.—Relative efficiency of various narrow-cut petroleum fractions of naphthenic and paraffinic composition for control of California red scale on navel orange trees at Riverside, California, as indicated by number of adult female scales before and after spray applications of August 18, 1950.

Oil	Scales per Fruit on			Scales per Leaf on		
	8/15/50	1/4/51	C.R.I.,[1] 1/4/51	8/15/50	1/4/51	C.R.I.,[1] 1/4/51
	Concentration, 2 Quarts/100 Gallons					
California spray-blending stock (naphthenic)	0.8	26.0	108	0.8	0.3	90
Fraction 5	0.9	26.3	94	1.1	0.5	114
Fraction 6	0.5	23.4	154	0.5	0.5	264
Fraction 7	0.5	24.9	144	1.2	0.2	38
Fraction 8	0.5	17.2	112	0.6	0.1	35
Carnation divider oil (paraffinic)	0.4	17.5	140	0.8	0.0+	8
Fraction 2	0.6	31.7	160	0.8	0.9	322
Fraction 3	0.7	26.9	130	0.5	0.6	323
Fraction 4	0.5	17.2	114	0.6	0.4	177
Fraction 5	0.7	19.8	91	0.8	0.0	0
L.S.D. at 5%		8.4			—	
	Concentration, 4 Quarts/100 Gallons					
California spray-blending stock (naphthenic)	0.5	19.4	122	0.8	0.1	39
Fraction 1	0.6	25.3	144	0.5	0.8	495
Fraction 2	0.2	11.6	209	0.3	0.1	47
Fraction 3	0.8	21.4	80	0.4	0.2	150
Fraction 4	0.4	15.2	109	0.6	0.1	42
Fraction 5	0.2	9.9	144	0.3	0.1	139
Fraction 6	0.5	13.0	83	0.7	0.1	35
Fraction 7	0.5	11.4	78	0.7	0.0+	9
Fraction 8	0.6	7.6	39	1.0	0.0+	3
Carnation divider oil (paraffinic)	0.7	10.2	48	1.0	0.0	0
Fraction 1	0.7	17.4	79	0.7	0.1	44
Fraction 2	0.6	17.9	89	0.8	0.3	110
Fraction 3	0.6	16.7	89	1.0	0.1	29
Fraction 4	0.4	10.6	83	0.4	0.1	36
Fraction 5	0.4	4.9	44	0.5	0.0+	4
Paraffin base 2	0.7	9.0	43	0.8	0.0	0
California spray oil (naphthenic)[2]						
Medium	0.4	12.7	100	0.3	0.1	100
L.S.D. at 5%		7.8			—	
	Concentration, 7 Quarts/100 Gallons					
California spray oil (naphthenic)[2]						
Light-medium	1.0	7.6	24	0.8	0.0	0
Medium	0.8	8.9	35	0.5	0.0	0

[1] Corrected relative infestation (Ebeling 1947); 100 = results with medium-grade oil at a concentration of 4 quarts per 100 gallons.
[2] California Department of Agriculture classification (Erb 1932; Marshall 1932).

listed in this table and in table 2 are the average numbers of live adult female scales per unit of fruit or leaf.

The data obtained from counts of scale populations on fruits in the plots established in Riverside in 1950 are presented graphically in figure 1. The fit of each line to its respective coordinate points was obtained by eye. Figure 1 illustrates our interpretation of the relation between the molecular weight of the petroleum hydrocarbons and the insecticidal efficiency observed. Molecular weights determined by means of the viscosity-gravity correlations proposed by Mills *et al.* (1946) were used for figure 1 because these correlations were used to obtain molecular weights of the fractions employed in the laboratory studies (Riehl & LaDue 1952).

DISCUSSION.—The posttreatment population counts of scales within 2 to 4 months after application on navel orange trees, and within 6 months after application on Valencia orange trees, were made on fruit within the same maturity cycle and, to a great extent, reflect the initial

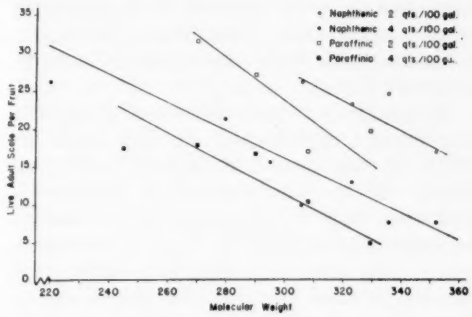

FIG. 1.—Correlation between the molecular weight of naphthenic and paraffinic petroleum hydrocarbons and their insecticidal efficiency in the field against California red scale, as indicated by the number of live adult females found per fruit 5 months after application of various narrow-cut petroleum fractions at concentrations of 2 and of 4 quarts per 100 gallons of aqueous spray mixture.

kill of scale on the peripheral count units. Later counts, 12 months after application, were made on the succeeding crop of fruit. The scale population density at this time represents the development of several generations. The density on the fruit occurs as a result of the tendency for scale crawlers to move to the peripheral parts of the tree. Thus, counts made on peripheral units a considerable time after application of the insecticidal treatment more nearly measure the degree of survival on all parts of the tree. Such estimates of population density show considerable variation, however, and are probably influenced by several limiting factors which are not recognized currently, and which may not exert their influence on the population in a uniform manner either singly or collectively.

Since citrus growers have generally employed a single application of petroleum spray oil a year on orange trees to control California red scale, the posttreatment population level approximately a year after treatment, in comparison with the pre-treatment population level, most nearly indicates the practical commercial value of the treatment.

Although the preliminary survey of the orchard selected for experimental plots indicated that each of the trees was infested with California red scale, the population level varied from tree to tree. Since each female scale produces a large number of progeny that are generally liberated into conditions suitable for their survival, and since there are two to three or more generations per year of California red scale in southern California, small differences in the pretreatment population density may exert great influence on the posttreatment population. This influence is more important in the low population densities than in high ones. Therefore, the relative efficiency of various insecticidal treatments cannot always be judged solely from the posttreatment data. Ebeling (1947) recognized this problem and proposed the term "corrected relative infestation" (C.R.I.) for the equation $x = 100(ab'/a'b)$, in which a and a' represent pretreatment and posttreatment counts for the standard treatment, and b and b' represent pretreatment and posttreatment counts for any given treatment of the experimental series. This equation expresses the change in population density caused by the various treatments of an experiment, in terms of the change in one of the treatments, usually a standard treatment. It thus applies a correction factor for the differences in the pretreatment infestation levels of the various plots. The value for the corrected relative infestation also facilitates comparison of the treatments.

In table 2, California medium-grade oil (Erb 1932; Marshall 1932) used at a concentration of 7 quarts per 100 gallons of spray mixture was selected as the standard. Since both light-medium-grade and medium-grade spray oils are used in southern California for the commercial control of California red scale, either of them might have been selected as the standard. Medium-grade oil is the so-called "heavier" (Smith 1932; Ebeling 1950) of the two oils and generally provides a slight gain in control in commercial practice.

The high frequency of zeros in the posttreatment count of March 22, 1949 (Table 2) for the Valencia orange grove at Canoga Park obviates the need for application of the equation for the corrected relative infestation.

In table 3, the zero value for the posttreatment infestation on leaves in the plots treated with medium-grade oil at a concentration of 7 quarts per 100 gallons of spray mixture limits the use of this treatment as a standard for the corrected relative infestation. However, in this experiment medium-grade oil was used at the concentration of 4 quarts per 100 gal-

lons, one of the concentration levels used for the narrow-cut fractions. Selection of the treatment in which medium-grade oil was used at 4 quarts as the standard for the corrected relative infestation offers the opportunity to compare the performance of the various fractions with a California spray oil at the same dosage level. The efficiency of any given fraction in terms of commercial field control in this experiment may be estimated by comparing its "C.R.I." value with that of either light-medium-grade or medium-grade oil used at a concentration of 7 quarts per 100 gallons of spray mixture.

It is the opinion of the authors that the data for the number of scales per leaf shown in table 3 principally reflect the efficiency of the various treatments for the control of California red scale on woody stems and branches, and the influence of the residual film of the treatment on the ability of the scale crawlers to settle and establish themselves. These data show inconsistency in the correlation of insecticidal efficiency with increasing molecular weight. It is likely that this is not representative but occurs as a result of the apparent inherent variability of California red scale. Evidence of considerable variability in this insect was also noted in laboratory studies (Riehl & LaDue 1952).

The posttreatment data of table 3 indicate relatively poor control in the terms of commercial practice, even for the conventional concentration of California spray oils. On the day the application work was started, the temperature increased rapidly and reached 95° F. (the maximum[3] for the Riverside district) by 12 noon. When it became evident that it might not be possible to continue the application work throughout the day, the spraying was stopped with the completion of the first replicate. This was done before the temperature reached 95° F., but later in the day the temperature rose to 113° F. On the second and third days, spraying was begun early in the morning, and a replicate was completed each day before the temperature reached 95° F. A similar procedure is commonly used commercially. It is likely, however, that the high temperatures prevailing for part of the day during the application work caused a more rapid dissipation of the oil from the foliage than usually occurs. Since all the various oils were exposed to comparable conditions in this experiment, their performance may thus have been exposed to a severe test.

From the evidence obtained from the experiment conducted at Riverside in 1950, it appears that the efficiency of spray oil for the control of California red scale may be decreased if application is made during periods when the temperature may reach a relatively high level during part of the day. It seems, therefore, that when the temperature is likely to reach the maximum limit for spraying in the district by midday, oil-spray application for citrus pest control should cease entirely for the predicted duration of such "hot spells."

The data for the number of adult female scales per fruit, from table 3, presented graphically in figure 1, show that the efficiency of petroleum hydrocarbons for the control of California red scale is associated with increasing molecular weight. This association is also evident for the numbers of scales per leaf, shown in table 3, and for the data of table 2. Although the distillation range of the fractions used in these experiments is much narrower than that of the oils used by Smith (1932) and Ebeling (1950), the evidence for the association of insecticidal efficiency with increasing molecular weight within the range of 220 to 360 agrees with their work.

Correlation of insecticidal efficiency with increasing molecular weight appears to be better for oils highly paraffinic in composition than for those of naphthenic composition. In laboratory work, Riehl & LaDue (1952) found that as molecular weight increased insecticidal efficiency reached a maximum and then decreased. For oils of naphthenic composition, maximum efficiency occurred at a molecular weight of 287, and for those of paraffinic composition, at 354. Such a turning point is not evident in figure 1. However, this is probably due to the fact that paraffinic oils of molecular weights higher than the maximum efficiency level found in laboratory studies were not used in the field experiments. Moreover, at least one generation of progeny occurred in all the field plots between the time of spray ap-

[3] The Agricultural Code of California, chapter 1a, section 160.5, authorizes the county agricultural commissioners to set maximum temperatures for oil spray application in the various localities.

plication and the first posttreatment count, and under these circumstances the residual film of oil would have exerted an effect on the settling of the crawlers. It is reasonable to assume that dissipation of the oil from the foliage would be inversely related to molecular weight. Therefore, in the field, the effect of the residual film appears to be as important as the initial kill of the adult females for the control of California red scale.

Ebeling (1936) showed that the fully developed adult female is the stage of California red scale least susceptible to oil, and that the younger stages are progressively more susceptible. It is therefore likely that the insecticidal efficiency of the various oils in the field tests is the sum of their performance in initial kill of adult females and in effect of residual film on settling and on mortality of crawlers.

The data obtained in these studies indicate that highly paraffinic oils are more efficient for control of California red scale than naphthenic oils, and that the insecticidal efficiency of petroleum spray oils for control of this scale can be increased by proper selection of the fractions used with respect to molecular weight and paraffinicity.

SUMMARY AND CONCLUSIONS.—Field experiments were conducted to study the efficiency of two series of narrow-cut, highly refined petroleum fractions, one naphthenic and the other highly paraffinic in composition, for control of California red scale on citrus. Selected physical and chemical properties of the oils are given. The various fractions were applied to orange trees in aqueous spray mixtures. The control obtained was estimated by counting the number of adult female scales per fruit and per leaf. The relation between insecticidal efficiency and increasing molecular weight is illustrated.

It is concluded (1) that the insecticidal efficiency of petroleum hydrocarbons for control of California red scale on citrus trees can be increased by proper selection of the fractions used as spray oils; (2) that the insecticidal efficiency of petroleum hydrocarbons for the control of this scale is correlated with increasing molecular weight within the range 220 to 360; and (3) that highly paraffinic oils are more efficient than naphthenic oils for the control of the California red scale.

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Narrow-Cut Petroleum Fractions of Naphthenic and Paraffinic Composition for Control of Citrus Red Mite and Citrus Bud Mite[1]

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The citrus red mite, *Metatetranychus* (*Paratetranychus*) *citri* (McG.), now ranks second in importance as a citrus pest in California (Boyce 1948). According to Quayle (1941), its occurrence in California had been noted by 1890, and by 1900 it had become an important pest of citrus. At that time sulfur was used for control of this mite. About 1924, however, it was observed that the citrus red mite was generally well controlled in orchards sprayed with oil to control the black scale, *Saissetia oleae* (Bern.). Since then spray oil has been the most important insecticide for the control of the citrus red mite, either primarily by applications made for this purpose or indirectly by applications made to control scale insects.

Infestation of lemon trees in California with the citrus bud mite, *Aceria sheldoni* (Ewing), was first recognized in 1937 (Boyce & Korsmeier 1941). As part of the investigations of this problem, these workers conducted extensive studies in both laboratory and field to ascertain the efficiency of available materials for the control of this pest. They found that the oil spray treatment commonly in use afforded the most generally satisfactory control of the citrus bud mite, as well as of the citrus red mite and of the black scale, which had to be considered in the pest control program for the area.

About 1939, Chapman *et al.* (1942, 1943) started investigations of the relation between chemical composition and insecticidal efficiency of various dormant and foliage spray oils used against several common insect pests of deciduous trees. They concluded that an oil which is highly paraffinic in character is the most desirable type. Recently, Riehl & LaDue (1952) reported results of laboratory studies which indicated that the insecticidal efficiency of spray oils against insects and mites attacking citrus may be considerably improved by proper selection with respect to structural character and molecular size.

Results of experiments to investigate the relation between chemical composition and physical properties of two series of petroleum fractions and their acaricidal efficiency against the citrus red mite and the citrus bud mite in the field are reported in this paper.

EXPERIMENTAL OILS.—Narrow-cut fractions of two oil stocks representing distinct naphthenic and paraffinic types were tested against citrus red mite and citrus bud mite in the field. The distillation ranges of these fractions are approximately 11 per cent of the range of spray oils used currently for the control of insect and mite pests of citrus. A description of the nature and a summary of the important physical characteristics of the two stock oils and the series of fractions of each are given in the first paper of this series (Riehl & Carman 1953).

PROCEDURE.—The various petroleum fractions used in these experiments were applied to the trees in aqueous emulsion prepared by the tank-mixture method (Smith 1932), using 4 ounces of blood albumin spreader per 100 gallons of spray mixture. The spray mixture was applied manually by means of conventional orchard spray equipment utilizing a high-pressure, reciprocating-type pump operating at a pressure of 600 pounds per square inch. The orifice of the discs used in the spray guns was 8/64 inch. The trees were sprayed with a full-coverage-type application, and a sufficient volume of material was applied to each tree to wet the foliage to the point of drip.

The experimental design included randomized blocks, with (1) three pairs of trees per plot replicated twice in the Somis and Santa Paula lemon orchards, (2) four pairs of trees replicated twice in the

[1] Paper No. 779, University of California Citrus Experiment Station, Riverside, California.

[2] The writers wish to express their appreciation to the Shell Oil Company for supplying the narrow-cut petroleum fractions and paraffin-base experimental oils used in this study, as well as the determination of their properties; to the Socony-Vacuum Oil Company for supplies of paraffin-base experimental oils; to the citrus growers who permitted placement of experimental plots in their orchards; and to M. J. Jesser and J. O. Complin, of the University of California Citrus Experiment Station, for valuable assistance.

Santa Paula Valencia orange orchard, and (3) one pair of trees replicated 3 times in the Riverside navel orange orchard.

The shape of the over-all experimental block varied in the different orchards and was determined in each instance by the shape of the orchard and the practical aspects of the application work. At Somis, the plots were laid out in two adjacent blocks separated by a eucalyptus windbreak, each block 14 by 22 rows. At Santa Paula, the block of lemon trees was 12 by 36 rows, and the block of Valencia orange trees was 6 by 45 rows. At Riverside, the block of navel orange trees was 15 rows by 18 rows.

In each of the orchards selected for experimental plots, population counts made prior to the date of the first spray application showed that the infestation of citrus red mite was generally distributed throughout the orchard in sufficient numbers to require commercial control measures. After the treatments had been applied, mite populations were counted at intervals until the date of the following scheduled treatment, unless it became necessary to re-treat the plot to avoid damage to the foliage. The degree of citrus red mite infestation was estimated by counting the number of adult mites on 32 leaves, 4 leaves from each of 8 terminals on each tree of each replicate. The counts were made in the field without removing the leaves from the tree.

The development of mite populations after the spray applications made in the fall of 1948 was observed through the winter and spring until the higher temperatures of the following summer became a limiting factor. The same procedure was followed in the plots of orange trees at Santa Paula for the applications made in August, 1949. Some of the plots of this experiment were discontinued the second year because mite control either by the oil fraction or by the dosage had not been adequate during the previous season. The plots in the lemon orchard at Santa Paula were discontinued at the end of the first season.

In many lemon orchards in southern California two applications of oil spray per year are required for citrus red mite control. For this reason, the decision was made to use a program of two applications (August and March) of the narrow-cut fractions on the plots in the lemon orchard at Somis during the 1949–50 season. By January, 1950, many of the plots required treatment for citrus red mite, and a few of the plots required treatment for citrus bud mite. For the citrus red mite a proprietary acaricide,[3] a wettable powder formulation containing 40 per cent bis (*p*-chlorophenoxy) methane, was used at a rate of 1 pound per 100 gallons of spray mixture; but for the citrus bud mite a conventional oil spray containing 1.75 per cent California medium-grade oil was required. Mite population counts for the August application were terminated in December. In March a second application was made to all of the plots except those re-treated with California medium-grade oil in January. The development of mite populations in the plots after this application was followed through June, 1950.

The plots for citrus red mite in the navel orange orchard at Riverside were established in August, 1950. Development of the red mite population was followed in these plots during the following fall, winter, and spring.

The two lemon orchards at Santa Paula and Somis are in districts subject to infestation by the citrus bud mite. Although the treatments were applied primarily to evaluate the efficiency of the various fractions for control of citrus red mite, it was also desirable to find out the degree of citrus bud mite control attained. New-growth buds (those which developed after treatment) were therefore dissected under 20× magnification to ascertain the percentage of buds infested with bud mite. Five buds were examined from each of 15 terminals per sample tree. Pretreatment counts were made to estimate initial mite population, and new foliage growth was sampled at intervals after each spray application to determine the development of bud mite populations.

RESULTS.—The relative efficiency of the various narrow-cut fractions of naphthenic and paraffinic composition, and of California spray oils, for control of citrus red mite is shown in table 1. The values listed represent the mean number of adult mites per terminal (4 leaves) per tree per sample count during the posttreatment interval described above for each of the application dates in the various orchards.

Observations during the posttreatment interval indicated that as the treatments

[3] Neotran.

Table 1.—Relative efficiency of narrow-cut fractions of naphthenic and paraffinic composition, and of California spray oils, for control of citrus red mite, as shown by mean number of adult mites per terminal (4 leaves) per tree for the given interval (in parentheses) following date of application.[1]

Oil	Lemon Plots				Orange Plots		
	Somis			Santa Paula	Santa Paula		Riverside
	Sprayed						
	Nov. 1948 (5/49–7/49)	Aug. 1949 (10/49–1/50)	Mar. 1950 (6/50–7/50)	Sept. 1948 (10/48–6/49)	Sept. 1948 (10/48–5/49)	Aug. 1949 (10/49–4/50)	Aug. 1950 (12/50–1/51)
Concentration, 1 Quart/100 Gallons							
California spray-blending stock (naphthenic)	10.9	5.7	149.9	55.7	35.7	—	
Fraction 5	11.2	8.7	—	63.6	53.2	—	
Fraction 6	8.4	11.2	—	12.8	33.8	—	
Fraction 7	15.9	7.6	—	16.6	12.2	—	
Fraction 8	7.2	4.3	—	7.8	4.3	—	
Residue 9	3.0	2.5	—	0.9	1.1	1.4	
Carnation divider oil (paraffinic)	2.2	2.7	—	1.0	2.2	1.2	
Fraction 3	7.0	10.7	—	—	—	—	
Fraction 4	10.2	5.8	—	—	—	—	
Fraction 5	2.7	2.4	33.2	1.3	3.7	3.2	
Residue 6	3.9	0.6	0.8	0.3	0.6	0.3	
Paraffin base 2	2.5	1.4	3.2	1.2	1.9	2.2	
Paraffin base 3	—	0.8	2.5	—	—	—	
Paraffin base 4	—	0.6	5.8	—	—	—	
L.S.D. at 5%	3.3	2.0	4.9	12.1	5.1	1.0	
Concentration, 2 Quarts/100 Gallons							
California spray-blending stock (naphthenic)	4.9	4.7	—	2.9	2.3	—	2.8
Fraction 5	9.4	8.2	—	11.9	12.8	—	20.5
Fraction 6	7.2	6.0	—	7.1	6.9	—	32.8
Fraction 7	5.0	1.2	65.8	2.9	1.3	—	12.2
Fraction 8	0.7	2.3	—	1.1	0.3	1.1	7.0
Residue 9	3.3	0.5	1.5	0.2	0.1	0.3	—
Carnation divider oil (paraffinic)	2.4	0.3	—	0.3	0.2	0.5	2.9
Fraction 2	—	—	—	—	—	—	31.7
Fraction 3	11.5	5.0	93.9	—	—	—	23.5
Fraction 4	7.5	1.9	—	—	—	—	9.1
Fraction 5	2.6	0.9	0.8	0.1	0.1	0.4	1.9
Residue 6	1.2	0.2	0.4	0.0+	0.1	0.2	—
Paraffin base 2	1.8	1.1	1.2	0.1	0.2	0.3	—
Paraffin base 3	—	1.0	2.5	—	—	1.5	—
Paraffin base 4	—	0.1	0.3	—	—	0.7	—
L.S.D. at 5%	1.4	2.2	3.5	1.9	1.3	0.5	5.8
Concentration, 7 Quarts/100 Gallons							
California spray oil (naphthenic)[2]							
Light-medium	2.4	1.4	—	0.3	1.0	0.4	1.8
Medium	4.8	0.7	1.8	0.4	0.3	0.4	4.7

[1] The mite populations were low in all plots from date of spray application to beginning of given posttreatment period.
[2] California Department of Agriculture classification (Erb 1932; Marshall 1932).

began to fail, the mite populations increased to some maximum and then declined. The interval prior to the appearance of mites, and the rate at which the numbers of mites increased, varied with the treatments. For this reason it was possible for the population to increase and a decline to occur in the mite population of plots sprayed with some of the ineffective treatments before mites appeared in noticeable numbers in the plots treated with the most effective sprays, and for this effect to confute the validity of a count made at the end of given intervals. However, the value obtained by calculating the mean number of mites per terminal per tree per count for a series of counts made at intervals during the post-

treatment period permits the derivation of index numbers on a comparable basis. Numbers obtained in this manner seem to provide a fair representation of the efficiency of the various treatments.

Curves plotted for the data obtained from plots in the lemon orchard at Somis for the application made in August, 1949, are shown in figure 1. The fit of the curve to its coordinate points was obtained by eye. Since the increasing order of magnitude is used for each axis, the relationship

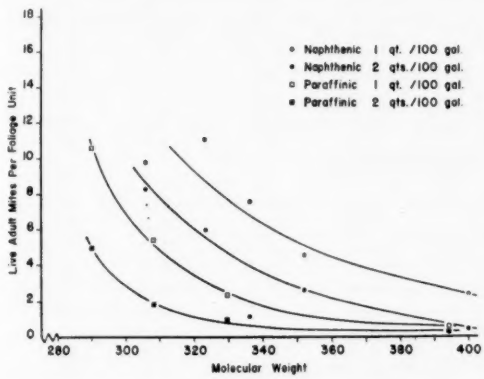

FIG. 1.—Correlation between efficiency and molecular weight of a series of fractions of naphthenic and paraffinic composition, at two dosage levels, against field populations of the citrus red mite at Somis, California, 1949.

for efficiency appears inversely, *i.e.*, the greatest efficiency is shown at the lowest point of the curve. Molecular weights determined by means of the viscosity-gravity correlations proposed by Mills *et al.* (1946) were used for figure 1 because these correlations were used to obtain molecular weights of the fractions employed in the laboratory studies (Riehl & LaDue 1952).

The relative efficiency of the various narrow-cut fractions for control of citrus bud mite infestations in the plots of the two lemon orchards are presented in table 2.

DISCUSSION.—Ring analysis data (Pearce & Chapman 1952) for 10 per cent fractions of the two stock oils used in our experiments indicate that within a series of fractions for each of these stocks the structural constitution is essentially constant. Therefore, correlations of pest control efficiency with molecular weight seem valid. In laboratory experiments (Riehl & LaDue 1952), the curves for correlations of viscosity with insecticidal efficiency of similar fractions for citrus red mite were similar in shape but were separated in the horizontal plane by the lower viscosity at given molecular weights for paraffinic vs. naphthenic composition. Correlations with molecular weight seemed to be a better index of insecticidal efficiency. Pearce *et al.* (1948) pointed out that change in boiling point, number of carbon atoms, aniline point, refractive index, density, and gravity within a series of fractions of an oil are all proportional to the change in molecular weight. For these reasons only curves of correlations with molecular weight have been shown.

Although the count values of the number of mites per foliage unit shown in table 1 represent the results of the control limitations exerted by the oil on populations of several successive generations of mites, the curves for the correlation of these values with molecular weight (Fig. 1) show the same general hyperbolic shape as those found for similar fractions in laboratory studies using the LD 95 of 24-hour eggs. It is also interesting to note that the correlations for the field data indicate a critical molecular weight in the range of 340, the critical value found in the laboratory experiments. This indicates that the ovicidal effect of petroleum spray oils is important to their efficiency against the citrus red mite in the field.

The curves in figure 1 show that the 2-quart concentrations of naphthenic and paraffinic fractions per 100 gallons of spray mixture provided more effective control of citrus red mite than the 1-quart concentrations. These data also indicate that a highly paraffinic oil has greater efficiency against this pest than one of naphthenic composition. This is illustrated further by the data presented in table 3, in which the values for the 2-quart concentrations for naphthenic fraction 7 (mol. wt. 336) and for paraffinic fraction 5 (mol. wt. 329) are compared with each other and with values for California citrus spray oils at a concentration of 7 quarts per 100 gallons. The values for the paraffinic oil are consistently lower than those for the naphthenic oil, and the differences exceeded the L.S.D. 0.05 in three of the five comparisons. In addition, the results presented in table 3 show that 2 quarts of paraffinic fraction 5 provided as good control of citrus red mite as 7

Table 2.—Relative efficiency of narrow-cut fractions of naphthenic and paraffinic composition, and of California spray oils, for control of citrus bud mite on lemon trees in two locations.

Oil	Mean Per Cent of Buds Infested					
	Santa Paula[1]		Somis[2]			
	9/28/48	8/10/49	11/4/48	8/8/49	12/5/49	8/1/50
Concentration, 1 Quart/100 Gallons						
California spray-blending stock (naphthenic)	51.5	33.5	5.0	22.2	14.5	67.5
Fraction 5	30.0	35.5	16.6	26.3	35.5	35.0[3]
Fraction 6	26.5	38.5	9.2	14.0	15.5	56.5
Fraction 7	48.0	30.5	2.5	18.3	18.0	65.3[3]
Fraction 8	29.5	19.0	3.4	30.6	21.5	38.0[3]
Residue 9	36.5	33.0	13.4	51.6	27.0	31.0[3]
Carnation divider oil (paraffinic)	36.5	47.5	10.0	35.3	23.5	37.0[3]
Fraction 3	—	—	7.5	51.3	9.7	12.5
Fraction 4	—	—	4.2	8.3	11.5	55.5
Fraction 5	40.0	22.0	15.0	15.3	11.0	56.5
Residue 6	55.0	29.0	5.0	30.0	17.0	44.0
Paraffin base 2	36.5	35.5	5.8	36.2	24.5	44.0[3]
Concentration, 2 Quarts/100 Gallons						
California spray-blending stock (naphthenic)	48.5	17.0	2.5	11.4	5.5	50.5
Fraction 5	26.5	29.0	7.5	14.0	20.0	27.5[3]
Fraction 6	30.0	25.5	10.0	16.4	9.0	37.0
Fraction 7	62.0	9.5	4.2	10.0	3.3	36.0
Fraction 8	20.0	14.0	18.4	22.8	6.0	24.0
Residue 9	33.0	14.5	3.4	7.3	4.5	40.5
Carnation divider oil (paraffinic)	33.5	15.0	10.0	17.4	5.5	41.5
Fraction 3	—	—	2.5	4.0	5.3	33.5
Fraction 4	—	—	10.8	3.6	8.3	34.0
Fraction 5	17.0	18.0	11.6	10.0	8.5	20.0
Residue 6	13.5	23.0	8.4	2.4	0.6	15.5
Paraffin base 2	23.0	17.0	8.4	6.7	10.5	44.5
Concentration, 7 Quarts/100 Gallons						
California spray oil (naphthenic)[4]						
Light-medium	36.5	17.0	4.2	8.3	2.0	29.0
Medium	14.5	17.0	8.4	7.6	2.0	25.5

[1] Spray applied 9/30/48.
[2] Sprays applied 11/12/48, 8/8/49, and 3/24/50.
[3] Re-treated with medium-grade emulsive spray oil on 1/4/50, because bud-mite infestation was sufficient for potential economic loss.
[4] California Department of Agriculture classification (Erb 1932; Marshall 1932).

Table 3.—Relative efficiency of narrow-cut fractions of naphthenic and paraffinic composition at a molecular weight of approximately 330, and of California spray oils, for control of citrus red mite on citrus trees in several locations.

Orchard	Average Number of Adult Mites per Foliage Unit After Treatment with—				
	Narrow-Cut Fraction (2 Qts./100 Gal.)		California Spray Oil[3] (7 Qts./100 Gal.)		L.S.D. at 5 Per Cent
	Naphthenic[1]	Paraffinic[2]	Light-Medium	Medium	
Lemon:					
Somis, 1948	5.04	2.58	2.38	4.83	1.39
Somis, 1949	1.17	0.92	1.35	0.73	2.17
Santa Paula, 1948	2.95	0.09	0.31	0.43	1.88
Orange:					
Santa Paula, 1948	1.31	0.13	1.02	0.26	1.34
Santa Paula, 1949	—	0.44	0.41	0.40	0.52
Riverside, 1950	7.04	1.92	1.75	4.67	5.80

[1] Fraction 7; average molecular weight, 336.
[2] Fraction 5; average molecular weight, 329.
[3] California Department of Agriculture classification (Erb 1932; Marshall 1932).

quarts of California medium-grade spray oil.

Further evidence of the efficiency of oils of paraffinic composition for the control of citrus red mite was obtained from a number of other experiments established in lemon orchards in the coastal zone to evaluate various materials for citrus red mite control. Treatments with paraffin-base oils ranging in average molecular weight from 316 to 359 were included in these experiments. In 17 out of 20 orchards the control of citrus red mite in plots treated with a spray mixture containing an oil of highly paraffinic composition at a concentration of 2 quarts per 100 gallons of spray mixture was as good as, or better than, that of comparable plots treated with a California medium-grade spray oil at a dosage of 7 quarts per 100 gallons. However, while the oil of highly paraffinic composition showed greater efficiency than that of naphthenic composition in the range of the critical value of 340 for molecular weight, the naphthenic oil attained an efficiency equivalent to that of the paraffinic at a molecular weight of 400 (Fig. 1).

Relatively little difference was evident between oils of naphthenic and paraffinic composition in laboratory experiments (Riehl & LaDue 1952) in which the insecticidal efficiency of narrow-cut fractions of these two oil stocks against 24-hour citrus red mite eggs was correlated with molecular weight. In the field, however, the oil of highly paraffinic composition was more effective for the control of citrus red mite. As pointed out above, comparison of the shape of the curves for correlation of efficiency with molecular weight from the field experiments with those of the laboratory experiments indicates that the ovicidal effect of the oils in the field was an important aspect of their insecticidal activity. The greater efficiency of the paraffinic oil in the field experiments may indicate that the film of oil for paraffinic composition persists on the plant surface longer than that of oil of naphthenic composition in the molecular weight range 330 to 400, since the data from the field experiments represent the summation of the efficacy of the fraction against several successive generations of mites. The difference in efficiency may be related to a difference in volatility, as suggested by Pearce & Chapman (1952).

Results presented in table 2 indicate that in the two lemon orchards at Santa Paula and Somis control of citrus bud mite was as good in plots treated with spray mixtures containing 2 quarts per 100 gallons of fraction 8 of the naphthenic stock, and of fractions 5 or 6 of the paraffinic stock, as in those sprayed with California light-medium or medium-grade spray oils used at the rate of 7 quarts per 100 gallons. Results obtained in these two lemon orchards give no indication, however, that control of citrus bud mite was associated with the paraffinicity of the oils or with any of the properties available for these series of fractions.

Paraffin-base oils ranging in molecular weight from 316 to 359 were included in experiments established in lemon orchards in the coastal zone to evaluate various materials for citrus red mite and citrus bud mite control. In 13 out of 20 comparisons these paraffin-base oils, used at dosages of 2 quarts per 100 gallons in spray mixtures prepared by the tank-mixture method with 4 ounces of blood albumin spreader per 100 gallons, were markedly less effective than California medium-grade emulsive spray oils used at the rate of 7 quarts per 100 gallons.

The amount of deposit obtained with a dosage of 2 quarts per 100 gallons of spray mixture may not be sufficient to permit creep of the oil into the crevices of the bud, a factor which may be necessary for control of the citrus bud mite with oil sprays. However, it might be possible to obtain better spreading of the oil film with other spray formulations than with that obtained with tank mixture.

SUMMARY AND CONCLUSIONS.—The efficiency of distinctly naphthenic and paraffinic types of highly refined petroleum oil for the control of two species of mites on citrus was studied in field plots in southern California. Two series of special narrow-cut fractions were used. In addition, the treatment series included other fractions comparable in distillation range to commercial foliage spray oils. The various oils were applied to the citrus trees in aqueous spray mixture. Correlations between molecular weight and acaricidal efficiency are shown for the citrus red mite.

The efficiency of petroleum fractions for the control of citrus red mite may be increased by proper selection for com-

position and molecular weight. Experimental results show that (1) paraffinic composition is more efficient than naphthenic composition, and that (2) the critical value of molecular weight for highly paraffinic petroleum oils occurs at approximately 340.

Observations of the control of citrus bud mite with various petroleum fractions used at concentrations of 2 quarts or less per 100 gallons of spray mixture show that (1) control at the commercial level was not obtained consistently, and that (2) no association between efficiency and molecular configuration or size was evident.

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A Butoxypolypropylene Glycol to Control the European Red Mite on Apples[1]

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During the course of laboratory evaluations of chemicals for insecticidal properties, it was found that some of the polyalkylene glycol derivatives possessed fly repellent (Granett *et al.* 1949) and acaricidal properties. One of these, a butoxypolypropylene glycol compound having an approximate molecular weight of 800,[4] gave considerable control of greenhouse red spider. Further investigation revealed that it was of practical value because of its effectiveness against European red mite, *Paratetranychus pilosus* (C. & F.), and because, due to its very low toxicity to mammals, it may be used on apples even shortly before harvest of the crop.

Studies with a few selected emulsifying and wetting agents for butoxypolypropylene glycol indicated that one of the higher sodium alkyl sulfates, the sodium salt of 5, 11-diethyl pentadecyl-8-sulfate, was toxic to mites and, in addition, possessed extremely good wetting properties. The optimum combination of these two ingredients which possessed high toxicity to all stages of mites, plus ease of formulation, was found to be a mixture[5] containing 80 per cent butoxypolypropylene glycol and 20 per cent sodium salt of 5, 11-diethyl pentadecyl-8-sulfate.

[1] Paper of the Journal Series, New Jersey Agricultural Experiment Station, Rutgers University, Department of Entomology, originally submitted for publication April 13, 1949.

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[3] This research was sponsored by Carbide and Carbon Chemicals Corporation, New York 17, N. Y. and conducted in part at Boyce Thompson Institute for Plant Research, Inc., Yonkers, N. Y. and Rutgers University.

[4] Experimental Acaricide 6, Carbide and Carbon Chemicals Corporation, New York City.

[5] Experimental Acaricide 2, Carbide and Carbon Chemicals Corporation, New York City.

Table 1.—Control of red spider mites, *Tetranychus bimaculatus* Harvey and *T. althaea* McGregor on bush beans.

Material	Conc.	Per Cent Control After 96 Hrs. Over Untreated Ck.	
		Both Nymphal Stages and Adults	Eggs
Experimental Acaricide 2	0.31%	88	85
	0.156	78	16
	0.08	71	11
	0.04	44	14
Experimental Acaricide 6	0.25	90	29
	0.125	88	23
	0.06	56	27
	0.03	55	18
Dinitro Compound	0.125	93	88
	0.06	84	86
	0.03	78	74
Parathion 25% Wettable	0.25	95	95
	0.125	79	84
	0.06	79	58
	0.03	67	24
Untreated		13	5

LABORATORY EVALUATIONS.—The initial studies with butoxypolypropylene glycol and mixtures were conducted in the laboratory against common greenhouse red spider mites. Bush bean plants (*Phaseolus vulgaris* L. var. *humilis* Alef. "Tendergreen" and "Cranberry") were heavily infested with all stages of mites, species *Tetranychus bimaculatus* Harvey and *T. althaea* McGregor, when the two primary leaves were almost fully expanded. Twenty-four hours after infestation, spray treatments were applied at 40 lbs. pressure to the plants on a turntable (Hartzell *et al.* 1948). Immediately after spraying three plants at each concentration, the plants were transferred to an air-conditioned room and kept under fluorescent light. Mortality counts were recorded after 96 hours. The results obtained with these materials and with a dinitro compound[6] and parathion are given in table 1. These data show that against greenhouse red spider mite species, it was necessary to use higher concentrations of Experimental Acaricides 2 and 6 in order to obtain kills equivalent to those obtained with dinitro compound or parathion.

Similar results also have been obtained against mites on corn, sweet potato, carnations, chyrsanthemums and roses. Some injurious effects, however, have been observed on certain varieties of roses.

FIELD INVESTIGATIONS, FIRST YEAR.—Considerable exploratory field testing with butoxypolypropylene glycol was done at New Brunswick, N. J. on small apple trees, Delicious, Stayman, and Turley varieties. Various mixtures with the sodium salt of 5, 11-diethylpentadecyl-8-sulfate were also tested. The results revealed that butoxypolypropylene glycol was not phytotoxic to apple foliage at 2 to 4 lb. per 100 gal. of water, gave control equal or superior to other materials such as a dinitro compound, hexaethyl tetraphosphate or summer oil emulsions and that formulations could be easily prepared with it which were compatible with DDT, sulfur, and a fungicide.[7]

FIELD INVESTIGATIONS, SECOND YEAR. Large scale tests to confirm previous findings were conducted on a block of mature apple trees containing Stayman, Paragon, and Smokehouse varieties. Five pretreatment sprays were applied[8] mainly to prevent scab infection. These treatments per 100 gallons of water consisted of: No. 1—3 lb. of lead arsenate, 3 lb. of lime, and 6 lb. of sulfur (April 16); No. 2—tops of trees sprayed with lime sulfur (April 26); No. 3—3 lb. of lead arsenate, 3 lb. of lime, 6 lb. of sulfur, and 12 oz. of flour (May 11); Nos. 4 and 5—1 lb. of DDT, 4 lb. of sulfur and 8 oz. of flour applied on May 24 and June 9. Despite these attempts, scab control was not good, particularly on Paragon and Smokehouse varieties. The weather was cool and wet, favoring disease and retarding mite development. However, mites began to multiply in June and spray treatments were applied as follows:

June 18. First spray applied to Replicate A which consisted of one tree each of Paragon, Smokehouse, and Stayman varieties. Rain followed in the evening.

June 30. Second spray applied to Replicate A. First spray applied to Replicate B which also consisted of one tree each of Paragon, Smokehouse, and Stayman varieties. Thus, two trees of each variety were used for each treatment. Rain followed in the evening.

[6] *DN-111*, contains 20% of dicyclohexylamine salt of dinitro-o-cyclohexyl phenol, Dow Chemical Company.

[7] Active ingredients 2-heptadecyl, 2-pentadecyl and 2-heptadecenyl glyoxalidines. Carbide and Carbon Chemicals Corporation, New York City.

[8] A 150-gallon capacity sprayer which was set to spray at 400 to 500 pounds pressure was used throughout.

Table 2.—Average number of European red mite nymphs and adults per leaf[1] on mature apple trees during 1948 spraying season.

Treatment	Lb./100 Gal.	Replicates	Sprayed 6/18/48 Counted 6/21	6/25	Sprayed 6/30/48 Counted 7/2	7/6	Sprayed 7/9/48 Counted 7/12	7/15	Counted 7/22	Fol. App.[2] 7/30
Experimental Acaricide 2	1.7	A	0.5	10	5	0.6	5	19	24	A
		B			5	4.5	6	26	52	A−
Experimental Acaricide 6	1.5	A	0.8	18	3.0	2.1	5	17	40	A
		B			2.6	4.3	45	36	42	B
Dinitro compound	1.5	A	2.9	8	7	7	17	17	32	B+
		B			6	4.6	17	17	45	B+
Parathion 25% Wettable	1.0	A	4.0	14	6	1.6	0.4	8	10	A
		B			3.5	2.5	2.0	9	19	A
Untreated Check		A	6	17	28	23	64	83	58	E
		B			20	17	34	87	48	E

[1] Figures represent the average of 10 leaves per tree.
[2] Foliage appearance: A—Green, normal; B—Pale green; E—Bronzed and defoliated.

July 9. Third spray applied to Replicate A and the second spray applied to Replicate B. A comparison of two sprays on Replicate B, and three sprays on Replicate A, was thus obtained.

Counts of nymphs, adults, and eggs with a brushing machine (Henderson *et al.* 1943) were made 2 or 3 and 7 days after each spraying. It was found that mite population continued to multiply up to 7 days after the third spray, *i.e.*, up to July 16. Direct comparison with the untreated check appears to be reliable up to this point at which time the check trees were thoroughly bronzed. There was a drop in population on untreated trees one week after this, and a decided drop 2 weeks later. The material used and the data collected are summarized in tables 2 and 3.

In the seven day count after the first spray, although Experimental Acaricide 2 and the dinitro compound gave better control than did parathion or Experimental Acaricide 6, none of the materials reduced nymphs and adult population more than 50 per cent over the untreated check. This may have been caused by the heavy rainfall shortly after spraying.

In the count made 1 week after the second spray treatment on Replicate A, Experimental Acaricide 2 reduced the nymph and adult population almost 100 per cent, and appeared to be better than

Table 3.—Average number of European red mite eggs per leaf on mature apple trees during 1948 spraying season.

Treatment	Lb./100 Gal.	Replicates	Sprayed 6/18/48 Counted 6/21	6/25	Sprayed 6/30/48 Counted 7/2	7/6	Sprayed 7/9/48 Counted 7/12	7/15	Counted 7/22
Experimental Acaricide 2	1.7	A	27	19	8	45	53	47	70
		B			20	66	116	96	68
Experimental Acaricide 6	1.5	A	32	29	14	88	75	94	92
		B			35	79	202	109	60
Dinitro Compound	1.5	A	53	38	39	172	143	122	101
		B			24	81	143	82	126
Parathion 25% Wettable	1.0	A	58	32	11	16	16	25	57
		B			25	16	41	33	58
Untreated Check		A	71	55	34	104	193	131	40
		B			33	95	115	128	43

Table 4.—Average number of European red mite nymphs and adults per leaf[1] on immature apple trees[2] during 1948 spraying season.

TREATMENT	LB./100 GAL.	1ST SPRAY 7/20/48 Counted 7/22	7/28	8/2	2ND SPRAY 7/28/48 Counted 7/30	8/4
Experimental Acaricide 6[3]	1.5	2	20		22	7
		15	21	7		
Experimental Acaricide 2	1.7	1	24		10	6
		9	17	14		
Experimental Acaricide 2 plus DDT[4]	1.7	18	24		16	9
		15	20	11		
Experimental Acaricide 2 plus DDT and fungicide[5]	1.7	7	16		9	3
		11	15	5		
Experimental Acaricide 2 plus Fungicide	1.7	8	11		5	5
		12	13	17		
Fungicide	1.0	11	20		6	6
		3	32	16		
DDT	1.0	12	20		11	9
		7	30	16		
Parathion 25% Wettable	1.0	9	29		6	4
		2	20	19		
Untreated Check		37	34		31	19
		37	34	32		

[1] Figures represent the average of 10 leaves per tree.
[2] The results of two tree scattered replicates are averaged except for untreated check for which 10 trees were observed.
[3] In the first spray 0.8 lb. of *Triton X-100* was used and in the second spray, 0.4 lb.
[4] Two pounds of a 50% wettable DDT powder used where reference to DDT is made.
[5] One pound of a 54% solution containing 2-hepta, 2 pentadecyl and 2 heptadecnyl glyoxalidines used where reference to fungicide is made.

parathion or the dinitro compound. The control from Experimental Acaricicide 6 was intermediate between parathion and the dinitro compound.

Seven days after the third spray, mite population was at its peak. Control on the A Replicates (three spray treatments) from Experimental Acaricides 2 and 6, the dinitro was about the same; 17 to 19 nymphs and adults were found per leaf as compared with 83 for the untreated check. On the parathion block the mites had also increased, but only to 8 per leaf.

Two weeks after the last spray, mites had decreased on the check trees but had continued to increase on the various treatments. This reduction in numbers on an untreated block is a recognized phenomenon apparently caused either by migration of mites from bronzed and dying leaves, or by the effect of predator action.

In general, three spray treatments of any of these materials were better than two sprays throughout the period covered by our observations. Although parathion and dinitro compound seemed to possess some residual action, more than one spray was required to give adequate control.

The trees were rated on July 30, 3 weeks after the last spray, for appearance according to color and abundance of the leaves, and these ratings also appear in table 2. Injury from mites is manifest by a change in leaf coloration from green to bronze. The best general appearance was shown by the parathion and Experimental Acaricide 2 blocks; the leaves on the blocks treated with Acaricide 6 and dinitro compound were not quite as green. The untreated check was thoroughly bronzed and partly defoliated when these observations were made.

In order to confirm the earlier findings that DDT and fungicide[7] used were compatible with butoxypolypropylene glycol, another series of experimental treatments

Table 5.—Average number of European red mite eggs per leaf on immature apple trees during 1948 spraying season.

Treated	Lb./100 Gal.	1st Spray 7/20/48 Counted 7/22	7/28	8/2	2nd Spray 7/28/48 Counted 7/30	8/4
Experimental Acaricide 6	1.5	34 43	35 35	 11	15	12
Experimental Acaricide 2	1.7	51 45	32 26	 12	11	9
Experimental Acaricide 2 plus DDT	1.7	61 86	43 46	 18	10	13
Experimental Acaricide 2 plus DDT and fungicide	1.7	67 104	39 57	 18	21	8
Experimental Acaricide 2 plus fungicide	1.7	41 55	28 40	 11	10	12
Fungicide	0.5	97 93	64 50	 9	15	16
DDT	1.0	60 52	41 63	 9	10	7
Parathion 25% wettable	0.25	69 66	20 25	 17	9	2
Untreated Check		87 87	86 86	 104	24	60

was set up with formulations of these materials applied to a mixed block of immature Stayman, Delicious, and Turley apple trees. Four trees each were sprayed and a second treatment of the same formulations was applied 8 days later to two of these trees, in order to obtain a comparison of one and two spray treatments. Counts on all trees were made 2 days after spraying and at weekly intervals. The mixtures used and the observations made are recorded in tables 4 and 5.

In general, the picture presented by this series of sprays is that control equivalent to parathion was obtained, although two spray applications were necessary for adequate control in all cases. For instance, one week after the first spray with a mixture containing Acaricide 2, DDT, and the fungicide population of nymphs and adults was reduced to 55 per cent of untreated check; one week after the second spray it was reduced to 84 per cent of untreated check. Reduction of nymphs and adults by parathion for this period was 28 per cent and 77 per cent. Acaricide 6 was found to be about as effective as Acaricide 2.

It should be noted that the fungicide also possessed considerable acaricidal properties by itself, being almost as effective as Acaricide 2 plus fungicide. According to reports from several sources, the observation has been made when this fungicide has been used in a regular apple scab control program, mite population has been very low in comparison to other treated blocks.

Toxicological Properties—Toxicological studies have shown that butoxypolypropylene glycol is not hazardous for use on animals or humans either while spraying or as a residue on crops. No primary irritation or sensitization of humans was found in patch tests with this chemical on over 200 subjects. No irritation was noticed from 2 to 10 hour applications of the undiluted material to face, arms, and legs of humans during repellency tests against black flies. The single dose oral LD-50 was 9.1 gm. per kg. to rats, and 23.9 gm. per kg. to rabbits. A single dose skin absorption trial of 20 ml. per

kg. killed only one of 10 rabbits. A 90-day inunction on rabbits of 1 gm. per kg. per day caused no injury beyond early transient erythema and desquamation.

In contrast to these figures, DDT is reported (Lehmen 1948) to have an acute oral toxicity to rats of approximately 0.25 gm. per kg. of body weight. Hexaethyl tetraphosphate is reported as being 35 times as toxic as DDT, and parathion 70 times as lethal.

SUMMARY AND CONCLUSIONS.—Preliminary tests in the greenhouse against common greenhouse red spider mite species on a wide range of plants indicate that satisfactory control can be obtained with a butoxypolypropylene glycol, approximate molecular weight 800, and formulations of this compound with the sodium salt of 5, 11-diethyl pentadecyl-8-sulfate. Field tests during two years against European red mite on apples with this compound at 24 oz. per 100 gal. (or the formulation at 1.7 lb.) in comparison with dinitro compound (20 oz.) and parathion (4 oz.) indicate that it gives control equivalent or superior to the former, but somewhat inferior to the latter. With heavy infestations of mites, two or three sprays of any one of these materials were necessary. No injury to apple foliage or fruit has been observed when the butoxypolypropylene glycol or formulations were used at effective concentrations.

Butoxypolypropylene glycol is of particular interest because of its very low toxicity to warm blooded animals. There is no operator hazard and the material may be used late in the season without danger of posionous residues.

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Abundance of Mites on Potatoes Treated with DDT, Sulfur, Parathion, or Malathion for Aphid Control

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The two-spotted spider mite, *Tetranychus bimaculatus* Harvey, has infested potatoes at Yakima, Washington, each year since 1946. It usually appears on potatoes about the time the first crop of alfalfa is cut for hay. Nearly all the potato fields become infested, but damage is most likely to occur where the crop is grown adjacent to alfalfa and following repeated applications of DDT. Landis and Davis (1947) reported that, either through coincidence or from cause, all potato fields found infested with mites in 1946 had received one or more applications of DDT dust prior to the occurrence of mite damage. Moreover, the greatest damage occurred in fields that had received four or five applications at 12- to 15-day intervals for the control of flea beetles and aphids.

During 1947 mite infestations were observed in four fields of potatoes starting early in July. All the fields had been dusted with DDT. In two of the fields, which had also been sprayed with a solution of 4.5 per cent of DDT in oil, heavy populations of mites developed from July 26 to September 5. Mite injury was also observed in 1948 in two fields that had been treated with DDT. Heavy damage from mites was observed in several potato fields that were located near alfalfa plantings in 1949. Aircraft applications of dusts containing 0.6 per cent of TEPP or 1 per

[1] In cooperation with the Washington State Department of Agriculture and the Washington Agricultural Experiment Stations.

cent of parathion at 40 pounds per acre were not effective in controlling the mites, although the parathion treatment reduced the infestation over 60 per cent after 7 days.

Incidental to work on the control of aphids on potatoes in central Washington from 1949 through 1952, the seasonal prevalence of the two-spotted spider mite was observed following treatments with various insecticides.

MATERIALS AND METHODS.—Multiple-application tests were conducted in 1 White Rose and 12 Netted Gem (Russet Burbank) potato fields. Fields that were planted in March or April and harvested in July or August produced early crops and those planted in June and harvested in October or November produced late crops.

The insecticides were applied with a power duster or by aircraft. The plots ranged from 200 to 1,200 feet in length and from 8 to 48 rows in width. Treatments were in a randomized-block design, with 3 to 4 replicates where aircraft was used and 4 to 8 where ground equipment was used exclusively. Applications with the crop duster were made at 25 pounds per acre except in field 9, where the rate was 30 pounds per acre, and in field 13 where it ranged from 26 to 31 pounds for the different dusts. Applications by aircraft were at 30 pounds of dust and 4.5 gallons of spray per acre in field 9, and 23 pounds of dust and 4.25 to 4.5 gallons of spray in field 12.

In most fields infestations were recorded as the number of leaves infested with mites or their eggs or showing mite damage in collections of 50 compound leaves per plot. In fields 9 and 12, where the plots were much larger, 150 leaves per plot were collected on each date. Samples were collected at 7-day intervals after each application, and at 2-week intervals after dusting was completed, until harvest or frost in fields 1 to 8, and in addition 1 day before and 3 days after applications in fields 9 to 13. Because of a variable number of treatments and replicate plots in the fields, and of differences in the number of samples that were taken during the season, the infestation data are reported in terms of the number of infested leaves per 1,000 from each treatment.

In 1949 ten dusts were tested on fields 1, 2, and 3. Two were proprietary and eight were laboratory mixtures. One proprietary dust contained 4 per cent of DDT and 80 per cent of sulfur, which had been fused together and reground. The other contained 5 per cent of DDT, 12 per cent of fused bentonite-sulfur, and sufficient dusting sulfur to make 75 per cent of total sulfur. A nonvolatile oil was added to two DDT dusts mixed at the laboratory. Pyrophyllite was used as the diluent for all laboratory-mixed dusts except as indicated. Four applications were made between May 18 and June 29 in field 1, between May 13 and July 2 in field 2, and between July 25 and September 2 in field 3.

In 1950 one proprietary and five laboratory-mixed dusts were applied with ground equipment. The proprietary dust was the same DDT 5 per cent plus sulfur 75 per cent used in 1949. Each of the other dusts contained either 5 or 10 per cent of DDT. Four of the DDT dusts also contained 50 per cent of sulfur, and one contained in addition 0.5 per cent of parathion. Two types of sulfur were used, a 3-micron wettable sulfur and a 325-mesh bentonite-sulfur. Five applications were made in field 4 between May 18 and July 7, three in field 5 between May 19 and June 19, three in field 6 between July 18 and August 25, three in field 7 between July 24 and September 9, and four in field 8 between July 18 and September 9.

In 1951 three treatments were compared in the early-crop field 9. An emulsion spray containing 4 per cent of DDT plus 0.4 per cent of parathion was applied by aircraft, and a proprietary dust mixture containing 5 per cent of DDT, 0.5 per cent of parathion, and 45 per cent of sulfur was applied by both aircraft and ground equipment. Five applications were made between May 22 and August 8. In the late-crop fields 10 and 11 five applications of several dust mixtures were made with ground equipment between June 18 and August 29. All the dusts contained 5 per cent of DDT, five of them contained from 12.5 to 50 per cent of dusting sulfur, and one also contained 0.5 per cent of parathion.

In 1952 the results of four aircraft applications of three sprays and two dusts were compared in field 12 on White Rose potatoes grown for an early crop. One of the sprays consisted of DDT dissolved in

a light mineral oil. The other sprays were of the emulsion type, and one contained malathion and the other DDT and parathion. One of the dusts was a mixture of DDT, parathion, sulfur, and talc; the other contained malathion with pyrophyllite as the diluent.

Four applications of three dusts were made with ground equipment in the late-crop field 13 between August 19 and September 23. One of the dusts contained 5 per cent of malathion; both the others contained 5 per cent of DDT and 0.5 per cent of parathion, and one of these also contained 5 per cent of sulfur.

Table 1.—Effectiveness of various dusts in controlling the two-spotted spider mite on Netted Gem potatoes in 1949.

Insecticide (Per Cent by Weight)	Pounds of Toxicant per Acre	Number of Leaves Infested per 1,000 (Entire Season)
Field 1 (early crop)		
DDT		
5	4.8	179
4+sulfur 80 (fused)	3.6+72.3	41
5+sulfur 75[1]	5.1+76.5	27
Sodium fluoaluminate		
33.3	32.2	140
33.3+parathion 0.5	33.8+ 0.5	77
Difference required for significance at odds of 99:1		48
Field 2 (early crop)		
DDT		
5	5.1	256
5+oil 2	4.9	240
3+oil 2	3.2	224
5+parathion 0.5	4.9+ 0.5	104
Parathion		
0.5	0.5	63
1	0.9	49
Difference required for significance at odds of 99:1		46
Field 3 (late crop)		
DDT		
5	4.6	2
5+oil 2	4.9	4
3+oil 2	2.9	4
4+sulfur 80 (fused)	3.6+71.0	1
5+sulfur 75[1]	4.7+71.2	trace
5+parathion 0.5	4.7+ 0.5	2
Sodium fluoaluminate		
33.3	30.3	2
33.3+parathion 0.5	29.7+ 0.4	trace
Parathion		
0.5	0.5	trace
1	0.9	0
Difference required for significance at odds of 19:1		3

[1] Contained 12 per cent of fused bentonite sulfur.

RESULTS.—*1949 tests.*—Mites were first observed in fields 1 and 2 on June 29, and the infestations persisted until harvest the first week of September. They were most abundant in plots that had been dusted with 5 per cent of DDT or with either 3 or 5 per cent of DDT plus 2 per cent of oil. The infestations were slightly lower in plots dusted with sodium fluoaluminate. The two proprietary dusts that contained 4 or 5 per cent of DDT with 80 or 75 per cent of sulfur, respectively, were most effective in the early-crop fields, although the dusts that contained either 0.5 or 1 per cent of parathion were nearly as good (Table 1).

Low mite infestations developed in the late-crop field 3, and there were few significant differences between treatments. Greatest infestations developed in plots that had been treated with the DDT-oil dusts and the smallest in plots that received 0.5 to 1 per cent of parathion or 75 per cent of sulfur as at least a part of the insecticide mixture.

1950 tests.—The mite infestations were of little consequence in field 4, where five applications had been made, but slight damage occurred in the latter part of July in field 5, where only three applications had been made. In both these early-crop fields, however, significantly greater infestations developed where a 5 per cent DDT dust was used than where mixtures containing 5 or 10 per cent of DDT with 50 or 75 per cent of sulfur were applied. The addition of 0.5 per cent of parathion to the DDT-sulfur dusts had a slight but not significant effect in improving control of the mites. No increase in control was observed with DDT dusts that contained 75 rather than 50 per cent of sulfur (Table 2).

Somewhat greater mite infestations developed in the late-crop fields than in 1949. Infestations were first observed on July 28, but increase was slow until August 18. Moderate damage occurred with some treatments from September 19 until October 1, when frost killed the plants. The infestations were much larger where 5 per cent DDT dust was used than where mixtures of DDT and sulfur were applied. Again the addition of 0.5 per cent of parathion to the DDT-sulfur mixture seemed to improve control. The DDT mixtures that contained 75 per cent of sulfur were not superior to those containing 50 per

Table 2.—Effectiveness of various dusts in controlling the two-spotted spider mite on Netted Gem potatoes in 1950.

Insecticide (Per Cent by Weight)	Pounds of Toxicant Per Acre	Number of Leaves Infested per 1,000 (Entire Season)
Field 4 (early crop)		
DDT		
5	6.3	20
5+wettable sulfur 50	6.2+61.5	3
5+bentonite-sulfur 50	6.8+67.6	2
5+wettable sulfur 50 +parathion 0.5	6.3+0.6+63.4	2
5+sulfur 75[1]	6.7+100.5	2
10+wettable sulfur 50	13.4+ 67.0	2
Difference required for significance at odds of 99:1		8
Field 5 (early crop)		
DDT		
5	3.5	32
5+wettable sulfur 50	3.5+34.5	10
5+bentonite-sulfur 50	4.0+39.5	12
5+wettable sulfur 50 +parathion 0.5	3.5+0.4+35.2	6
5+sulfur 75[1]	3.8+56.4	11
10+wettable sulfur 50	7.4+37.1	9
Difference required for significance at odds of 99:1		14
Field 6 (late crop)		
DDT		
5	3.7	43
5+wettable sulfur 50	3.6+35.5	15
5+bentonite-sulfur 50	3.5+34.7	16
5+wettable sulfur 50 +parathion 0.5	3.6+0.4+36.0	12
5+sulfur 75[1]	3.6+53.3	23
10+wettable sulfur 50	7.4+37.0	13
Difference required for significance at odds of 99:1		18
Field 7 (late crop)		
DDT		
5	4.1	39
5+wettable sulfur 50	3.5+35.2	15
5+bentonite-sulfur 50	3.5+35.3	14
5+wettable sulfur 50 +parathion 0.5	3.9+0.4+38.5	5
5+sulfur 75[1]	4.1+61.1	4
10+wettable sulfur 50	7.5+37.4	7
Difference required for significance at odds of 99:1		16
Field 8 (late crop)		
DDT		
5	5.5	26
5+wettable sulfur 50	5.2+52.2	10
5+bentonite sulfur 50	5.2+52.3	11
5+wettable sulfur 50 +parathion 0.5	5.2+0.5+51.5	4
5+sulfur 75[1]	5.4+81.3	12
10+wettable sulfur 50	11.9+54.7	12
Difference required for significance at odds of 99:1		13

[1] Contained 12 per cent of fused bentonite sulfur.

cent. No greater infestation developed with 10 than with 5 per cent of DDT.

1951 tests.—The first mites were observed in field 9 on July 1, but the infestation remained low until July 20, after which it increased until the plants matured about August 8. Greater infestations developed in the plots sprayed by aircraft with the DDT-parathion emulsion than in plots dusted by ground equipment with DDT-parathion-sulfur. Airplane applications did not appear quite so effective as applications by power ground equipment (Table 3).

Mites were first observed in fields 10 and 11 on July 2. The infestations remained low until mid-August and then increased rapidly until the season ended the first week of October. As was the case in 1950, the infestations were heavier in fields of late- than early-crop potatoes. Most injury developed where the 5 per cent DDT dust without sulfur was used. The number of leaves infested with mites decreased as the sulfur was increased from 12.5 to 50 per cent. The addition of 0.5 per cent of parathion to the dust containing DDT and 50 per cent of sulfur was of no benefit in one field, and although lower infestations resulted in the other field the difference in control was not significant. The substitution of talc for pyrophyllite as a dust diluent resulted in no difference in control.

Table 3.—Effectiveness of various dusts and sprays in controlling the two-spotted spider mite on Netted Gem potatoes in 1951.

Insecticide (Per Cent by Weight)	Pounds of Toxicant per Acre	Number of Leaves Infested per 1,000 (Entire Season)
Field 9 (early crop)		
DDT		
5+parathion 0.5+sulfur 45 (dust)		
Applied by aircraft	7.5+0.8+67.5	8
Applied by ground equipment	7.2+0.7+64.8	1
4+parathion 0.4 (spray, applied by aircraft)	7.5+0.8	17
Difference required for significance at odds of 19:1		9
Field 10 (late crop)		
DDT (dusts, applied by ground equipment):		
5	5.8	106
5+sulfur 12.5	6.1+15.3	73
5+sulfur 25	6.2+30.9	46
5+sulfur 50	6.0+59.8	29
5+sulfur 50[1]	6.3+66.3	25
5+sulfur 50+parathion 0.5	5.7+0.6+57.3	12
Difference required for significance at odds of 99:1		32
Field 11 (late crop)		
DDT (dusts, applied by ground equipment):		
5	5.5	126
5+sulfur 12.5	5.4+13.2	124
5+sulfur 25	5.9+29.4	98
5+sulfur 50	6.0+60.4	50
5+sulfur 50+parathion 0.5	5.3+0.5+53.1	52
Difference required for significance at odds of 99:1		61

[1] Talc was used as a diluent in this dust; pyrophyllite in all the others.

1952 tests.—Mites were first observed in the early-crop field 12 on May 29, but, as was the case in 1950 and 1951, the infestation did not increase to the same extent as on the late crop. The DDT-oil spray seemed to be the least effective, although the infestation was not significantly different from that which developed after the other treatments (Table 4).

Table 4.—Effectiveness of various dusts and sprays in controlling the two-spotted spider mite on potatoes in 1952.

Insecticide (Per Cent by Weight)	Pounds of Toxicant per Acre	Number of Leaves Infested per 1,000[1] (Entire Season)
Field 12 (early crop, White Rose)		
DDT(applied by aircraft):		
5+parathion 0.44 +sulfur 15 (dust)	4.6+0.4+13.7	trace
4+parathion 0.64 (spray)	6.1+1.0	trace
4.5+oil (spray)	6.1	6
Malathion (applied by aircraft):		
5 (dust)	4.7	1
1.7 (spray)	2.5	trace
Field 13 (late crop, Netted Gem)		
DDT (applied by ground equipment):		
5+parathion 0.5 (dust)	6.3+0.6	117
5+parathion 0.5+sulfur 5 (dust)	5.6+0.5+5.3	119
Malathion (applied by ground equipment):		
5 (dust)	5.2	59

[1] Difference not significant by the *F* test.

In the late-crop field 13 the malathion dust seemed to be superior to either of the dusts that contained DDT and parathion, with and without sulfur, but again the difference was not significant.

SUMMARY.—During June or July most potato fields in the Yakima Valley of Washington become infested with the two-spotted spider mite, *Tetranychus bimaculatus* Harvey. Fields of alfalfa are a considerable source of the mites.

Records of mite infestations that were taken incidental to experimental dusting and spraying of potatoes for aphid control from 1949 to 1952 showed that the infestations of mites developed rapidly where DDT dusts or sprays were applied and that damage occurred occasionally to the fall crop.

The mites developed more rapidly following applications of DDT than of sodium fluoaluminate. The addition of sulfur to DDT dusts prevented the rapid increase of mites. Fifty per cent of sulfur in the dust mixture gave good control, and no additional benefit was obtained from 75 or 80 per cent of sulfur. Dusts containing 0.5 to 1 per cent of parathion were approximately equal to DDT dust containing 50 per cent of sulfur, but the plots became reinfested more rapidly. Four or five applications of a dust containing 5 per cent of DDT, 0.5 per cent of parathion, and 50 per cent of sulfur prevented injury from mites throughout the season. Malathion, applied as a 5 per cent dust and a 1.7 per cent spray, gave good immediate control, although the residual action was not as long as with the DDT-parathion-sulfur dust.

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Slurry Treatment for the Control of Stored Corn Insect Pests[1]

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The use of pyrethrum-piperonyl butoxide and other compounds for the control of stored grain insects in bins has stimulated interest in the use of such compounds in the slurry method of treating shelled corn. Reports from seed dealers as well as unpublished preliminary tests conducted by the author have indicated some promise of control with pyrethrum-piperonyl butoxide mixtures in the slurry method of treatment.

There are advantages to the slurry method of treatment. Low percentages of material of low residual toxicity to warm blooded animals may be used, thus reducing the possibility of inadvertently poisoning farm animals that are fed left-over or discarded treated corn. Furthermore, the material is applied directly to the grain itself in a process that covers each kernel. This does not necessarily kill the stages of the pest that may be hidden within the grain. However, the completeness of the coverage lessens the possibility of pests entering the grain. The cost of the treatment is not excessive.

The disadvantages of the slurry treatment limit the usefulness of this system to the treatment of seed. The cost of a

[1] Contribution from the Entomology Department, North Carolina Agricultural Experiment Station, Published with the approval of the Director of Research as paper No. 489 of the Journal Series.

[2] Grateful acknowledgment is made to Mrs. H. (Anne) Howden, who was responsible for all the laboratory work in these tests.

commercial slurry treater may be too high for most small seed producers. Furthermore, it should be remembered that this method is more useful as a preventative measure rather than a cure-all, particularly where such compounds as pyrethrum-piperonyl butoxide are used. Consequently, with certain formulations, this method of treatment may not be effective in reducing the number of weevils developing in corn.

In order to check on the effectiveness of slurry treatments, a series of laboratory tests were conducted in 1951–1952 with four compounds used in 10 formulations.

Table 1.—Materials used in corn slurry tests and effect on germination.

Treatment Number	Materials	Parts Used per Million Parts Shelled Corn	Per Cent Germination 1 Month After Treatment[2]
1	Isoparaffinic oil[1]	3,500	72
2	Lindane	0.025	78
3	Lindane	.5	80
4	Lindane	10	82
5	1% pyrethrins-10% piperonyl butoxide	50	84
6		100	84
7		200	89
8	0.75% pyrethrins-10% piperonyl butoxide	50	86
9		100	85
10		200	93
11	Water (check)	5,075	85

[1] Isoparaffinic oil used without dilution.
All other insecticides applied as dilute solutions in 230 ml. of water to 100 lbs. of corn.
[2] Stored at 74° F.

The corn selected for these tests was N. C. 27, a hybrid that is normally not heavily attacked by rice weevils. The lot of corn selected for the test was a 1950 stock that had been kept as ear corn in the husk until 2 weeks prior to treatment on November 29, 1951. The corn was cleaned before treatment and showed signs of being moderately to heavily infested with the rice weevil, *Sitophilus oryza* (L.). Additional checks on the effectiveness of the different treatments were made by noting the condition of corn and the development of weevils in corn stored under different methods of storage.

MATERIALS AND METHODS.—As shown in table 1, four compounds were used in this test, including two different pyrethrum-piperonyl butoxide preparations. One of these contained 1 per cent pyrethrins and 10 per cent piperonyl butoxide and the other, 0.75 per cent pyrethrins and 10 per cent piperonyl butoxide.[3] An isoparaffinic oil[4] and lindane[5] were used.

The shelled corn was treated in a Gustafson type slurry treater. In the usual method of treatment, 230 ml. of fluid are added to 100 pounds of corn. This amount of fluid is added in 10 equal lots of 23 ml. to the corn as it is fed through the treater. The seed and insecticide are thoroughly mixed. Corn was treated in batches of 50 pounds. The slurry treater was thoroughly cleaned after each treatment.

POST-TREATMENT STORAGE AND EXAMINATION.—After treatment each batch was separated into two parts for storage and further examination. One part, consisting of 4 pints of corn, was stored in four covered jars in a heated laboratory, where air temperatures averaged about 74° F. The remaining portion of the original 50 pounds was divided into four equal parts and stored in heavy cotton twill bags in an unheated room where inside air temperatures paralleled outside air temperatures closely.

The laboratory jar samples were kept from November 29, 1951, the date of treatment, until April 2, 1952, when they were discarded. These jars were examined on January 29 and April 2, 1952. Jar examinations consisted of removing and counting the insects present. In addition, a count was made of egg, feeding, and exit holes. The hole examinations were made by staining a sample of 100 kernels removed from each jar and noting the number of different type holes. The staining technique used was that developed by Frankenfeld (1948).

The larger samples stored in bags in the unheated room were examined on February 29, 1952 and on June 20, 1952. At the February examination, one pint jar of corn was removed from each bag and kept in the heated laboratory until May 26, 1952, when they were discarded. These jars were examined on April 14 and May 26 in a manner similar to that described above for the regular laboratory jar samples.

WEEVILS IN CORN STORED AT 74° F.—A summary of the effect of the different slurry treatments on the development of the weevils in corn stored at 74° F. is presented in table 2. The results of this test

[3] Pyrethrum-piperonyl butoxide mixtures supplied by the U. S. Industrial Chemicals Co.
[4] A by-product of high-octane gasoline production, supplied by the Socony-Vacuum Oil Co., Inc.
[5] Supplied by the California Spray-Chemical Corp.

Table 2.—Effectiveness of slurry treatments on development of the rice weevil in corn stored at 74° F.

Treatment[1] Number	Average No. Weevils per Pint Jar After				Buildup of Weevils From 2 Mos. to 4 Mos. of Storage[2]	Per Cent Kill of Weevils[3]	Per Cent Moisture	
	2 Months		4 Months				1 Day After Treatment	At End of 4 mos. Storage
	Alive	Dead	Alive	Dead				
4	1	58	0	10	−1	99.4	13.1	9.1
3	93	28	43	27	−50	37.6	12.8	9.1
1	10	7	59	8	49	26.6	12.0	9.1
11	63	8	109	18	46	21.6	12.8	8.4
10	148	26	270	41	122	19.5	13.3	8.4
8	116	12	218	29	103	13.5	13.0	9.5
2	91	12	154	18	63	12.1	13.2	9.3
5	82	12	385	27	303	8.9	13.7	12.5
7	133	24	767	7	634	8.0	12.6	22.4
9	148	14	630	43	482	7.9	12.9	13.3
6	110	7	346	12	236	5.8	12.8	11.3

[1] See table 1 for description of treatments.
[2] Average number of weevils per jar at 4 months of storage less average number at first 2 months of storage.
[3] Average for 2 months of storage plus 4 months of storage.

were based on counts of weevils made at 2 months and at 4 months after storing. Treatment No. 4 (10 parts of lindane per 1 million parts of corn by weight) had the least number of weevils developing at 2 and at 4 months after storing. The average kill of weevils for these two counting dates, 99.4 per cent, was the highest kill recorded in all the treatments. This treatment also had the lowest buildup of weevils from 2 to 4 months after storing. The lowest kill, 5.8 per cent, was recorded in treatment No. 6 (100 parts of 1 per cent pyrethrins-10 per cent piperonyl butoxide per 1 million parts of corn by weight). The greatest buildup of weevils and a relatively low kill was recorded in treatment No. 7 (200 parts of 1 per cent pyrethrins-10 per cent piperonyl butoxide per 1 million parts corn). The untreated lot of corn, treated with water only, had a comparatively small buildup of weevils and a kill of 21.6 per cent.

With the exception of treatment No. 4, already referred to and treatment No. 3 (0.5 part lindane per 1 million parts corn) all the treatments had pronounced increases of weevils from 2 to 4 months after storing.

CONDITION OF CORN STORED AT 74° F.—The condition of corn was judged by the increase in number of different types of holes caused by the weevils. These holes, or punctures, are of three types: (1) punctures that the females make in which to lay their eggs, (2) feeding punctures made by the adults and (3) emergence hole made by the adult for getting out of the kernel. Emergence holes are easily seen by the naked eye but the feeding and egg punctures are seen best after the kernels are stained and examined under magnification according to the method reported by Frankenfeld (1948). Table 3 summarizes the counts made immediately after treatment and just before storage compared with counts made at 4 months after storing at 74° F. An increase in all three types of holes was recorded after 4 months of storage for all treatments except in two instances—treatment No. 4, wherein there were fewer egg punctures, and treatment No. 1, wherein were recorded fewer emergence holes at 4 months after storing than just before storage began. These apparent decreases may have been due to sampling error. In all other cases, there were marked increases in the number of all three types of holes. The greatest increases were recorded in treatments No. 5, 6, 7, 9 and 10. All of these treatments were made with varying amounts of pyrethrum-piperonyl butoxide. Treatment No. 8 (0.75 per cent pyrethrins-10 per cent piperonyl butoxide at 50 parts per million) had a relatively moderate increase in all three types of holes.

RANK OF EFFECTIVENESS OF THE SLURRY TREATMENTS.—In general, there was some degree of correlation in the effectiveness of the different slurry treat-

Table 3.—Condition of slurry-treated corn stored at 74° F. based on egg and feeding punctures and emergence holes.[1]

Treatment No.[2]	Before Treatment			Per Cent Increase in No. Holes at 4 Months Over No. at 2 Months of Storage		
	Egg Punctures	Feeding Punctures	Emergence Holes	Egg Punctures	Feeding Punctures	Emergence Holes
1	75(86)[3]	71(93)	38(31)	15	31	(−18)
2	70(75)	63(102)	28(63)	7	62	13
3	80(119)	87(150)	34(48)	49	72	41
4	48(40)	47(71)	26(32)	(−16)	50	23
5	46(347)	48(403)	30(75)	650	740	150
6	52(369)	77(249)	34(54)	610	223	59
7	54(1020)	84(1028)	28(98)	1788	1123	250
8	80(131)	88(154)	27(47)	64	73	75
9	76(510)	89(465)	39(77)	571	422	98
10	91(261)	93(304)	35(61)	186	227	74
11	38(57)	52(87)	18(37)	50	67	105

[1] Based on counts of 100 kernels from each treatment.
[2] See table 1 for description of treatments.
[3] Figures in parenthesis are the results after 4 months' storage.

ments based on all the criteria used, namely, the three types of punctures, the buildup of weevils from 2 to 4 months after storing, and the per cent kill. Table 4 lists the treatments according to their rank in order of decreasing effectiveness with respect to the criteria mentioned above. Treatments No. 1, 3 and 4 appear to be the most effective according to this ranking. Treatment No. 11 (treated with water only) showed up surprisingly well according to the criteria used except that of "emergence holes." Treatment No. 7 was the poorest of all with respect to egg and feeding punctures but it ranked slightly better on kill.

Table 4.—Rank in effectiveness of slurry treatments on development of weevils in corn after 4 months' storage at 74° F., based on different criteria.

Rank[1]	Buildup from 2 to 4 Months' Storage	Per Cent Kill[2]	Punctures		Emergence Holes
			Egg	Feeding	
A	3[3]	4	2	1	5
B	4	3	4	4	1
C	1	1	1	11	3
D	11	11	11	2	6
E	2	10	3	3	8
F	8	8	8	8	11
G	10	2	10	6	10
H	6	5	5	10	9
I	5	7	6	9	2
J	9	9	9	5	5
K	7	6	7	7	7

[1] Decreasing effectiveness from A to K.
[2] Based on kill at 2 months of storage plus kill at 4 months of storage.
[3] See table 1 for description of treatments.

Table 5 summarizes the development of the rice weevil in corn stored under different temperatures and categories. In the second storage category, corn was stored at "outside" temperatures[6] for 3 months and it was then transferred to storage at 74° F. for 12 weeks. In the third category, corn was kept at outside temperatures from the time of treatment on November 29, 1951, until June 20, 1952. The average maximum temperatures for the unheated storage during these months ranged from 56.3° F. in February to 93.9° F. in June. The minimum ranged from 36.5° F. in November and December to 69.7° F. in June.

In the second storage category, which consisted of initial storage at outside temperatures followed by storage at 74° F., there was a very noticeable reduction in number of weevils per pint jar, compared to the number obtained in corn stored 4 months at 74° F. The moisture content of corn in the second storage category ranged from 11.8 per cent to 12.7 per cent. The reduced number of weevils in the second storage category is believed to have been the result of the low temperatures to which this corn was initially subjected for 3 months before it was transferred to storage at 74° F.

[6] The term "outside" is used to refer to the temperatures in an unheated storage room where inside air temperatures paralleled closely atmospheric air temperatures.

Table 5.—Comparison of number of weevils[1] in slurry-treated corn stored at 74° F. with similarly treated corn stored otherwise.

Treatment No.[2]	Storage at 74° F. No. of Weevils After		Per Cent Moisture		Storage in Unheated Room					
					For 3 Months Followed by Storage at 74° F.				After 6 Months	
					No. of Weevils After		Per Cent Moisture		No. of Weevils	
	2 Months	4 Months	Before Storage	After 4 Months' Storage	6 Weeks	12 Weeks	Before[3]	After[4]	Alive	Dead
1	17	67	12.1	9.1	33	44	12.2	11.5	4	32
2	103	172	13.2	9.2	64	93	12.7	11.6	17	39
3	121	70	12.8	9.1	43	14	12.6	10.6	3	22
4	59	10	13.1	9.1	22	5	12.4	10.4	1	17
5	94	412	13.7	12.5	45	41	12.1	10.8	4	37
6	117	358	12.8	11.3	61	145	12.4	11.3	9	20
7	157	774	12.6	22.4	72	76	12.2	11.0	12	54
8	128	247	13.0	9.5	70	86	11.8	11.3	5	23
9	162	673	12.9	13.3	93	194	12.4	12.2	17	92
10	174	311	13.3	8.4	62	87	12.4	11.4	9	26
11	71	127	12.8	8.4	29	32	12.2	11.0	7	14

[1] Average number weevils per jar based on 4 replicates.
[2] See table 1 for description of treatments.
[3] Per cent moisture after 3 months "outside" storage.
[4] Per cent moisture following 12 weeks of subsequent storage at 74° F.

The reduction in weevil development recorded in the second storage period was only temporary. A count of weevils at 12 weeks after the beginning of storage at 74° F. showed an increase in number of weevils over that recorded in the count made 6 weeks previously except in the two lots treated with the higher dosages of lindane. The increase was most pronounced in treatments 6 and 9—the two pyrethrum-piperonyl butoxide mixtures used at 100 parts of insecticide per 1 million parts of corn.

The retardation of weevil development was most pronounced in the corn stored at the cooler outside temperatures, where after 3 months no weevils were found in any of the treatments. After 6 months of outside storage, all treatments had live and dead weevils. The heaviest lindane treatment had the lowest number of weevils.

Increase in the rate of weevil development and abundance was correlated with an increase in the number of emergence holes made by weevils provided that sufficient time had elapsed for the emergence of one or more generations of weevils. Table 6 gives a summary of the number of weevil emergence holes recorded in corn stored at different temperatures. In most instances, there were increases in the number of emergence holes. In general, these increases were more noticeable in corn stored at 74° F. than in the other two storage categories. In the storage at 74° F., the increase in all samples in the number of emergence holes was 85 per cent after 4 months of storage. In the unheated storage followed by 12 weeks of storage at 74° F., the increase was 52 per cent while in the unheated storage alone, the increase in emergence holes was 47 per cent after 6 months of storage. These increases in number of emergence holes re-

Table 6.—Number of weevil emergence holes in slurry-treated corn stored at different temperatures.[1]

Treatment Number[2]	Storage at 74° F.		Unheated Storage				
			For 3 Mos. Followed by Storage at 74° F.				
	Before	After 4 Months	Before	For 6 Weeks	For 12 Weeks	Before	After 6 Months
1	38	31	34	28	39	34	30
2	28	63	28	40	46	28	40
3	34	48	30	39	40	30	34
4	26	32	23	28	33	23	30
5	30	75	19	28	24	19	25
6	34	54	22	31	35	22	41
7	28	98	24	37	37	24	49
8	27	47	26	32	45	26	40
9	39	77	38	43	84	38	45
10	35	61	30	44	41	30	66
11	18	37	26	25	32	26	32
Total	337	623	300	375	456	300	442
Per cent increase		85			52[3]		47

[1] Based on counts of 100 kernels per treatment.
[2] See table 1 for description of treatments.
[3] Average for 6 weeks plus 12 weeks.

flect to some degree the influence of temperature on the development of weevils in stored corn.

SUMMARY.—Corn hybrid N. C. 27 infested with the rice weevil, *Sitophilus oryza* (L.), was treated with different dilutions of lindane, isoparaffinic oil, and two formulations of pyrethrum-piperonyl butoxide in a commercial slurry-treating machine in an attempt to control this insect. Materials, except isoparaffinic oil and water, were applied as dilute water solutions at the rate of 230 ml. of fluid per 100 lbs. of corn. Corn was stored in three different categories: (1) at 74° F., (2) in unheated storage followed by storage at 74° F., and (3) in unheated storage.

Effectiveness of control was based on weevil development, kill of weevils, and increase in number of egg and feeding punctures and adult weevil emergence holes at various periods following treatment and storage. Lindane, at 10 parts to 1 million parts by weight of corn, was the most effective material used. Isoparaffinic oil, 3,500 parts per million parts, and lindane at 0.5 part per million parts of corn were next best.

Corn stored at 74° F. for 4 months had the most weevils and the greatest amount of weevil damage. Corn in unheated storage for 6 months had the least weevils and smallest amount of weevil damage.

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Control of the Boll Weevil and the Bollworm with Organic Insecticides in 1952[1]

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Late-season damage by the boll weevil, *Anthonomus grandis* Boh., and the bollworm, *Heliothis armigera* (Hbn.), in central Texas in 1952 afforded an opportunity to conduct field experiments at Waco with various dusts and sprays for the control of these insects. Although the bollworm was a factor in all the experiments, the boll weevil was of primary importance in seven experiments and the bollworm in two. The extreme drouth prevented outstanding increases in yield on plots receiving the various insecticides, but considerable information was obtained on their effectiveness in the control of these insects.

PROCEDURE.—Five experiments were conducted in small plots of 0.2 acre or less, and four experiments in plots of 2 to 10 acres. In experiments 1, 2, and 3 the plots were 16 rows wide and 0.2 acre in size; in experiments 8 and 9 they were 12 rows wide and 0.125 acre in size. The plots were arranged in randomized blocks with four replications of each treatment. In the large-scale experiments, experiments 4 through 7, there were no replications of treatments.

In all experiments dusts were applied with rotary hand guns.

In the small-plot experiments the emulsions were applied with a 4-row cart-type hand-drawn machine constructed especially for spraying small areas. Three nozzles were used per row. A small engine was used to drive the pump. The cart was mounted on two bicycle wheels and drawn by one man at about 3 miles per hour. In the large-scale experiments emulsions were applied with 8-row tractor attachment, low-pressure and low-volume spray machines, with three nozzles per row. In all experiments sprays were applied at a pressure of 60 pounds per square inch.

The procedure and method of recording data were the same as those reported by Ewing and Parencia (1943). The cotton fleahopper, *Psallus seriatus* (Reut.), the cotton aphid, *Aphis gossypii* Glov., and spider mites, Tetranychidae, did not cause

[1] Presented at the meeting of the American Association of Economic Entomologists at Galveston, Texas, February 26 and 27, 1953.

[2] In cooperation with the Texas Agricultural Experiment Station.

[3] The writers acknowledge the assistance of K. P. Ewing, under whose general supervision this work was conducted.

Table 1.—Effectiveness of several organic insecticides against boll weevils and bollworms. Waco, Texas, 1952.

TREATMENT (STRENGTH OF DUSTS AND DOSAGE OF ACTIVE INGREDIENT PER ACRE IN SPRAYS)	RATE OF APPLICATION PER ACRE	PER CENT			POUNDS OF SEED COTTON PER ACRE	
		Weevil Punctured Squares	Bollworm Infestation			
			Injured Squares	Injured Bolls	Total	Gain Over Check
Boll Weevil Experiments						
Experiment 1 (Applications on July 29, Aug. 2, 7, 12, 15, 21)						
Dust (per cent):	*Pounds*					
BHC, gamma 3+DDT 5+sulfur 40	16	33	3	3	721	162
Sprays (Pounds):	*Gallons*					
BHC, gamma 0.45+DDT 0.75	4.5	39	3	3	638	79
EPN 0.375+DDT 0.75	4.5	29	4	5	685	126
0.5+DDT 0.75	4.5	33	4	3	729	170
0.625+DDT 0.75	4.5	25	4	5	724	165
Untreated check	—	51	4	5	559	—
Difference required for significance, 5 per cent level	—	9	—	—	75	—
Experiment 2 (Applications on July 10, 15, 22, 26, 31, Aug. 5)						
Sprays (pounds):						
Toxaphene 1.9+DDT 0.92	4.5	14	6	2	556	126
Aldrin 0.33+DDT 0.67	4.5	12	8	4	543	113
Dieldrin 0.27+DDT 0.67	4.5	11	6	4	559	129
Endrin 0.33	4.5	15	5	2	584	154
Heptachlor 0.33+DDT 0.67	4.5	14	7	4	541	111
Untreated check	—	34	8	4	430	—
Difference required for significance, 5 per cent level	—	5	—	—	65	—
Experiment 3 (Applications on Aug. 7, 12, 16, 26)						
Dusts (per cent):	*Pounds*					
Lime-free calcium arsenate containing 1 per cent parathion	14	10	3	2	801	98
Toxaphene 20+sulfur 40	16	12	2	2	782	79
Sprays (pounds):	*Gallons*					
Metacide 0.31+DDT 0.75	4.5	16	3	3	737	34
Endrin 0.2	4.5	17	2	2	700	−3
0.3	4.5	10	2	1	801	98
Untreated check	—	37	2	2	703	—
Difference required for significance, 5 per cent level	—	10	—	—	78	—
Experiment 4 (Applications on July 14, 21, 25, 30, Aug. 4, 8, 13, 19)						
Sprays (pounds):						
Aldrin 0.34+DDT 0.81	6	21	10	7	864	481
Dieldrin 0.28+DDT 0.81	6	14	10	7	1007	624
Heptachlor 0.34+DDT 0.81	6	18	12	8	1020	637
Toxaphene 2+DDT 1[1]	6	25	11	6	932	549
Untreated check	—	55	4	3	383	—
Experiment 5 (Applications on July 14, 21, 25, 30, Aug. 4, 8, 13, 19, 26)						
Sprays (pounds):						
Metacide 0.5	6	24	14	10	1018	336
Toxaphene 2+DDT 1	6	30	9	6	1002	320
Untreated check	—	64	4	4	682	—
Experiment 6 (Applications on July 22, 26, 31, Aug. 5)						
Sprays (pounds):						
Toxaphene 3	6	23	4	2	558	142
Endrin 0.2	6	16	8	5	585	169
EPN 0.5+DDT 0.75	6	17	6	4	607	191
0.375+DDT 0.75	6	17	6	4	587	171
Untreated check	—	84	4	1	416	—
Experiment 7 (Applications on Aug. 7, 12, 16, 26)						
Dusts (per cent):	*Pounds*					
Toxaphene 20+sulfur 40	20	22	4	2	844	249
Lime-free calcium arsenate containing 1 per cent of parathion	17	9	3	2	898	303
Lime-free calcium arsenate containing 1 per cent of methyl parathion	17	11	4	2	761	166
Untreated check	—	75	2	3	595	—

Table 1.—(Continued)

Treatment (Strength of Dusts and Dosage of Active Ingredient per Acre in Sprays)	Rate of Application Per Acre	Per Cent: Weevil Punctured Squares	Per Cent: Bollworm Infestation: Injured Squares	Per Cent: Bollworm Infestation: Injured Bolls	Pounds of Seed Cotton per Acre: Total	Pounds of Seed Cotton per Acre: Gain Over Check
Bollworm Experiments						
Experiment 8 (Applications on July 21, 25, 30)						
Dusts (per cent):	*Pounds*					
BHC, gamma 2+DDT 10+sulfur 40	14	.02	5	4	795	208
BHC, gamma 3+DDT 5+sulfur 40	14	1	6	5	748	161
Lime-free calcium arsenate containing 2.5 per cent of DDT and 1 per cent of parathion	14	2	7	6	680	93
Sprays (pounds):	*Gallons*					
BHC, gamma 0.45+DDT 0.75	4.5	0	7	7	685	98
Toxaphene 2+DDT 1	4.5	0.2	5	6	706	119
Untreated check	—	1	14	12	587	—
Difference required for significance, 5 per cent level	—	—	3	2	96	—
Experiment 9 (Applications on July 21, 25, 30)						
Dusts (per cent):	*Pounds*					
DDT 10+methyl parathion 1	16	2	5	5	753	154
Sprays (pounds)	*Gallons*					
Toxaphene 2+DDT 1	4.5	1	6	7	724	125
3	4.5	1	10	10	612	13
Endrin 0.25	4.5	2	11	10	681	82
0.375	4.5	1	7	6	715	116
Untreated check	—	1	12	13	599	—
Difference required for significance, 5 per cent level	—	—	3	5	77	—

[1] Toxaphene was used at 2.25 pounds per acre in first 2 applications.

appreciable damage in any of the experiments.

The insecticide treatments used in these experiments are given in table 1. The toxaphene dust and the dust mixtures containing BHC, DDT, and sulfur were standard commercial products. The other dusts and emulsifiable concentrates were obtained from various manufacturers.

RESULTS AGAINST BOLL WEEVILS.—In experiments 1, 2, and 3 each treatment reduced the boll weevil infestation significantly below that of the untreated check, and significantly more seed cotton was produced on the treated plots of experiments 1 and 2.

In experiment 1 the highest dosage of EPN plus DDT gave significantly better control than BHC plus DDT when both treatments were applied as sprays. The two highest dosages of sprays containing EPN plus DDT and the dust containing BHC plus DDT plus sulfur gave significantly higher yields than the spray containing BHC plus DDT.

In experiment 2 the differences in control and yield between the various treatments were not significant, although each was significantly better than the check.

In experiment 3 plots dusted with lime-free calcium arsenate containing parathion or toxaphene plus sulfur and those sprayed with 0.3 pound of endrin produced significantly more seed cotton than that sprayed with 0.2 pound of endrin or the untreated check. With Metacide plus DDT there was no significant increase in yield over that of the check. There was no difference in control between treatments.

Experiment 4 was conducted on creek-bottom land. The cotton was planted in April, but injury from early-season insects had delayed fruiting. On July 14, when treatment was begun, the plants had set very few bolls and blooming was light. After two applications had been made, a heavy bollworm infestation developed; therefore, in subsequent applications dosages of all insecticides were increased. The bollworm injury in the untreated check was light. There was very little difference in bollworm control obtained with the various insecticides. Dieldrin plus DDT gave the best boll weevil con-

trol. Increases in yield over untreated check plots were good, in view of the fact that most of the cotton was produced during dry weather. The yield was lowest on the aldrin plus DDT treated plot, but most of this difference was probably due to land variation rather than to poorer insect control.

Experiment 5 was conducted in the same field as experiment 4, but the cotton was planted early in June. Metacide applied as a spray gave slightly better boll weevil control than toxaphene plus DDT. The bollworm infestation that developed in the treated plots was heavy but of short duration. Even though the dosage of Metacide was increased to 0.625 pound per acre during the peak of the bollworm infestation, it gave no appreciable control. However, the yield was not affected since the plants treated with Metacide produced enough cotton after the infestation was over to replace the fruit lost to bollworms. Increases in yield on plots treated with Metacide and with toxaphene plus DDT were, respectively, 336 and 320 pounds of seed cotton per acre.

In experiment 6 both the EPN-DDT and the endrin sprays gave better boll weevil control than did toxaphene. There were only slight differences in yield from the various treatments.

In experiment 7 both dusts containing lime-free calcium arsenate gave better boll weevil control than toxaphene plus sulfur. This difference was not apparent in the infestation record made 4 days after the third application, when 11 per cent of the squares in the toxaphene-treated plots were punctured, compared with an average of 7 per cent on the plots treated with lime-free calcium arsenate. On the ninth day 50 and 17 per cent were punctured, respectively, an indication that residual toxicity was longer in the latter treatments. Squares were scarce at the time, and an application was made for boll protection. Increases in yield over the untreated check averaged 234 pounds of seed cotton per acre after the lime-free calcium arsenate treatments and 249 pounds after the toxaphene treatment.

RESULTS AGAINST BOLLWORMS.—In experiment 8 a dust containing sufficient BHC to give 2 per cent of the gamma isomer, 10 per cent of DDT, and 40 per cent of sulfur gave the best bollworm control and the highest yield. The boll injury records show that injury was significantly lower after this dust treatment than the others except the one containing 3 per cent of gamma isomer of BHC, 5 per cent of DDT, and 40 per cent of sulfur. However, each treatment reduced the infestation significantly below that of the check. Significantly more seed cotton was produced on all the treated plots except the one receiving lime-free calcium arsenate containing DDT and parathion. The BHC-DDT-sulfur containing 2 per cent of the gamma isomer of BHC gave a significant increase in yield over that containing DDT and parathion in lime-free calcium arsenate and over the BHC-DDT spray.

In experiment 9 all treatments except toxaphene at 3 pounds and endrin at 0.25 pound per acre reduced the bollworm infestation significantly below that of the check, and all treatments except toxaphene gave a significantly higher yield of seed cotton. The DDT-methyl parathion dust, the toxaphene-DDT spray, and the 0.375-pound dosage of endrin spray each gave a significantly higher yield than toxaphene spray.

OTHER EXPERIMENTS.—Several large-scale experiments were conducted in which treatment was made for the control of insects early in the season and again for late-season infestations of boll weevils and bollworms, but they are not reported in detail in this paper. Where endrin was applied in a spray at 0.3 pound per acre, it gave control of both insects equal to that obtained with toxaphene at 2 pounds plus DDT at 1 pound.

SUMMARY.—Small-plot and large-scale field experiments in which insecticides were applied as dusts and as low-volume sprays were conducted at Waco, Texas, during 1952 for the control of late-season infestations of the boll weevil, *Anthonomus grandis* Boh., and the bollworm, *Heliothis armigera* (Hbn.).

In a small-plot experiment an EPN-DDT spray applied at a rate of 0.5 or 0.625 pound of EPN plus 0.75 pound of DDT per acre gave boll weevil control equal to that obtained with a dust containing sufficient BHC to give 3 per cent of the gamma isomer, 5 per cent of DDT, and 40 per cent of sulfur. Sprays applied at the following acre-dosages were equally effective in controlling the boll weevil: toxaphene 1.9 pound plus DDT 0.92

pound; aldrin 0.33 pound plus DDT 0.67 pound; endrin 0.33 pound; dieldrin 0.27 pound plus DDT 0.67 pound; and heptachlor 0.33 pound plus DDT 0.67 pound. In another small-plot experiment conducted for boll weevil control, lime-free calcium arsenate containing 1 per cent of parathion, and 20 per cent of toxaphene plus 40 per cent sulfur dusts, and a 0.3-pound dosage of endrin spray produced a significant increase in yield over that produced by a 0.2-pound dosage of endrin spray.

In a large-scale experiment Metacide applied in a spray at an average rate of 0.5 pound per acre gave slightly better boll weevil control than toxaphene plus DDT spray but failed to control bollworms. Lime-free calcium arsenate containing 1 per cent of parathion showed a longer period of residual toxicity to boll weevils than 20 per cent toxaphene plus 40 per cent sulfur dust.

In one small-plot experiment against bollworms a dust containing sufficient BHC to give 2 per cent of the gamma isomer, 10 per cent of DDT, and 40 per cent of sulfur gave the best control and produced the highest yield. It produced a significant increase in yield over that produced by lime-free calcium arsenate containing 2.5 per cent of DDT plus 1 per cent of parathion dust and over that produced by the BHC-DDT spray. In another bollworm control experiment DDT plus methyl parathion dust, and toxaphene plus DDT spray and endrin applied in a spray at the rate of 0.375 pound per acre each produced a significant increase in yield over that produced by the toxaphene spray.

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Trends in Pink Bollworm Control in the Laguna of Mexico

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The Laguna region of Mexico is located in the States of Durango and Coahuila. It has an area of approximately 2,500,000 acres and is an old lake bed, which is the drainage basin of the Nazas and Aguanaval Rivers. It has an altitude just under 4,000 feet and is surrounded by high mountains. The climate is mild and very dry, the average annual rainfall being less than 8 inches. All crops have to be produced under irrigation. Water for this purpose is obtained from the Nazas and Aguanaval Rivers and from about 3,000 deep wells. Since irrigation water is limited, less than one-fifth of the region is in cultivation. Cotton and wheat are the principal crops, although a sizable area is devoted to grapes, alfalfa, and truck crops. During the last 5 years cotton has been grown on about 257,000 acres, with an average annual production of 255,863 bales. This is approximately one-fourth of Mexico's cotton production.

The pink bollworm, *Pectinophora gossypiella* (Saund.), was introduced into the Laguna in 1911, and by 1916 it had become generally distributed over that region. In the early 1920's the infestations were uniformly heavy and causing severe commercial damage. By the late 1920's the insect had become so well established that in most cotton fields of the region almost all the bolls were infested by the latter part of each season.

During those early years little effort was made to control the pink bollworm. The growers, while conscious of the injury to the crop, preferred to accept the damage rather than to put forth any effort toward control. Cotton-seed-heating equipment was installed in most gins, but its use was not carefully supervised and consequently many units were operated without heat or at temperatures too low to be effective in killing larvae.

CULTURAL PRACTICES.—It was not until 1942 that a serious effort was made to apply cultural practices and to supervise the operation of cotton-seed-heating

equipment. At that time a campaign was started to secure destruction of all cotton stalks as soon as possible after the cotton was picked. Experience soon showed that a definite date could be established for the completion of stalk destruction, so that it was possible to put the plan on a more exact and workable basis.

For several years it has been required that all cotton stalks be destroyed by October 31. In general this destruction is accomplished on a voluntary basis. However, the Mexican Department of Agriculture may find growers who fail to comply. Previously it was the custom to cut the cotton stalks and then rake and pile them until they were dry enough to burn. Recently many growers have been cutting the stalks with rotary cutters or shredders and plowing them under. This method has the advantage of returning organic material to the soil as well as giving equal or better pink bollworm control. It is also required that all cotton land be deeply plowed as soon as possible after the stalks have been destroyed. The deadline for completion of this work has been established as December 31. Growers who fail to meet the plowing deadline are also liable to fines. Approximately 90 per cent of the growers complete both stalk destruction and plowing prior to the deadlines, and usually the other 10 per cent at an early date.

A careful check is maintained in fields to prevent the growth of soca, or sprout, cotton. Since 1942 it has been illegal to cultivate soca cotton. This regulation is rigidly enforced.

The owners of all gins in the region are required to maintain cotton-seed-heating machines and operate them as part of the continuous ginning process, under supervision. It is also required that all gin trash be destroyed by burning. In most gins the trash is blown directly from the trash collectors to incinerators, to reduce the possibility of scattering pink bollworms. Segregation of seed cotton, pressed lint, seed, and bagging must be maintained at all times. The gin yards, houses, and seed-cotton storages must also be kept clean in order to limit the harboring of pink bollworm larvae. Since 1942 this program of cultural control and general gin sanitation has been followed remarkably well.

CONTROL WITH INSECTICIDES.—For many years tests have been conducted in an attempt to find an insecticide that would be effective in combating the pink bollworm. Although a great many chemicals were tested, it was not until DDT entered the picture that a satisfactory material was found. In preliminary experiments in 1946 DDT gave promise of success. The next year large-scale tests demonstrated that the use of DDT was effective and economic. In 1948 the cotton growers of the Laguna began using the new insecticide, and each succeeding crop season has seen its use extended until at present it is difficult to find a cotton field in which DDT is not used.

DDT is the only insecticide that has yet been found to give satisfactory control of the pink bollworm. However, it is necessary to combine it with other insecticides for the control of certain cotton insects that are not controlled by DDT. The mixture found to be most economical and satisfactory for use in the Laguna contains 10 per cent of DDT, sufficient BHC to give 2 per cent of the gamma isomer, and 40 per cent of sulfur. This material is applied as a dust at the rate of 15 kilograms per hectare. Good control has been obtained with as few as 3 applications during the season, but as many as 11 have sometimes been required. The usual number is about 6 or 7.

Two general schedules of insecticide applications for pink bollworm control are employed in the Laguna. One is to wait until infestation is observed in squares, blooms, or bolls, and then apply the insecticide at weekly intervals. The other is to start applications early, when the cotton plants have from 6 to 8 leaves, and to make the second application 7 days after the first, and the third 21 days after the second. Additional applications are made as needed. The second schedule is the one more generally in use, as it results in lower pink bollworm populations and better all-round insect control with fewer applications. Both power-driven ground dusters and aeroplane dusters are employed in the Laguna. Some growers have tried single-outlet space dusters, but have failed to obtain satisfactory control because of poor plant coverage.

COMBINED PRACTICES.—Cultural control practices and gin sanitation are being continued, and when supplemented by the use of insecticide are giving outstanding control of the pink bollworm. Most grow-

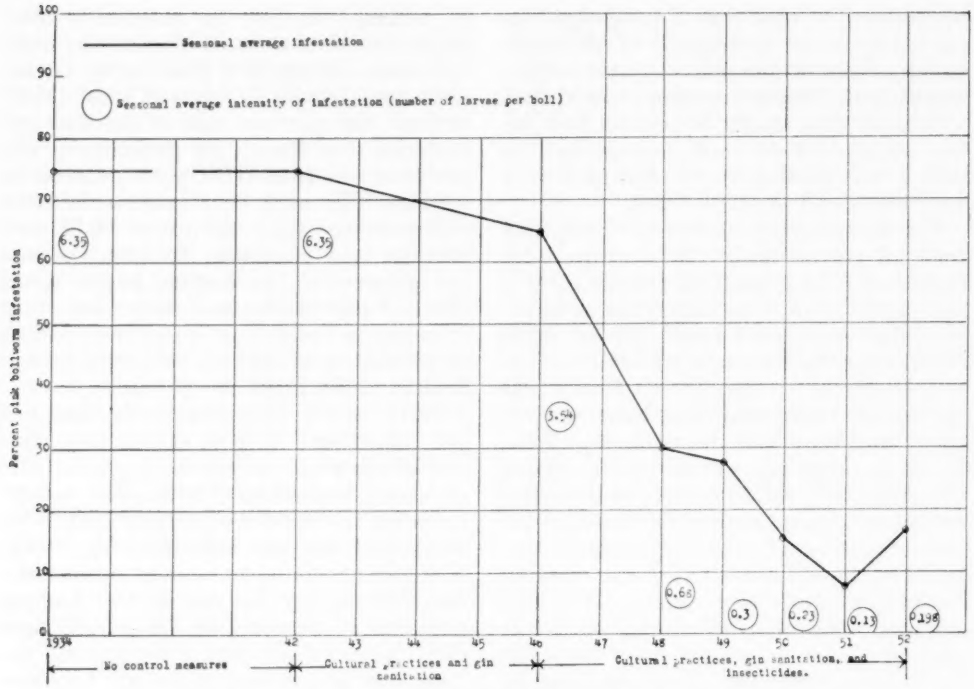

FIG. 1.—Effect of control practices on pink bollworm infestation in the Laguna region of Mexico, 1934 to 1952.

ers of the area agree that their use is a "must" in the production of a profitable cotton crop. The campaign to obtain control of the pink bollworm has met with remarkable success. For the first 5 years cultural practices and gin sanitation were the only means employed. Although there was a considerable reduction in populations, this reduction was not sufficient to prevent rather heavy damage to the cotton crop. Since 1948, by supplementing these measures with insecticide applications it has been possible to reduce populations to a point where little or no commercial damage occurs.

The seasonal average infestations and the intensity of infestation (the number of larvae per boll) from 1934 to 1952 are shown in figure 1. In 1934, when practically nothing was done to control the pink bollworm, there was an average infestation of 75 per cent in green bolls, with an average of 6.35 larvae per boll. From 1934 to 1942 only fragmentary infestation records are available. However, gin-trash examinations in 1942 indicate that the infestation was fully as high as in 1934. By 1946, after a general program of cultural control and gin sanitation had been in use for 5 years, the average infestation had been reduced to 65 per cent in green bolls, with 3.54 larvae per boll. It is thus seen that the measures in use had reduced the pink bollworm population nearly 50 per cent.

Although insecticides were first used in the pink bollworm control program in 1946, it was not until 1948 that sufficient cotton acreage was treated to show marked reduction in populations. In that year approximately 40 per cent of the cotton acreage of the Laguna was treated with insecticide to supplement the other practices. The infestation in green bolls was reduced to 30 per cent, with only 0.68 larva per boll. During the next three seasons the work with insecticides was greatly improved and expanded. Each season the pink bollworm population was appreciably lower than the season before, until in 1951 only 7.79 per cent of the green bolls were infested, with 0.13 larva per boll.

With pink bollworms reduced to a point where they caused little or no commercial damage, the growers became careless and neglected to destroy the cotton stalks until late in 1951. In many fields plowing

was neglected, and in many other fields it was accomplished from 6 weeks to 2 months late. As a result, in the spring of 1952 the cotton growers of the entire area found themselves faced by a high potential pink bollworm population that had been allowed to build up in their fields. The early-season infestation in blooms was 5.3 per cent, which was the highest since DDT had been used for control. Alarmed by this condition, growers started an intensive use of insecticide and were able to avert some of the damage. However, it was necessary to make three or four more applications than had been necessary during the preceding 3 years. In spite of this intensive program, the pink bollworms built up to a point where they caused severe damage in many fields. The seasonal average infestation in green bolls increased to 16.8 per cent, with 0.198 larva per boll. This failure to make full use of the cultural practices for a single season demonstrates that no one method will keep the pink bollworm under control.

The control program also improved the yield and grade of cotton. For the 5-year period 1936–40, before the control program was started, the average yield was 1.4 bales per hectare and 58.51 per cent of the crop graded middling or better; for the 3-year period 1949–51, after the use of insecticide had became general, the average yield was 2.7 bales per hectare and 78.16 per cent of the crop graded middling or better. This shows an increase in yield of 1.3 bales per hectare and a 25-per cent increase in that part of the crop grading middling or better.

Laboratory Experiments on the Role of Insects in Sewage Oxidation Ponds[1]

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Use of oxidation ponds as a method for secondary treatment of sewage has been rather widely adopted in the State of California because it represents one of the most economical means known for sewage treatment, availability of land and climatic conditions permitting. Essentially, this process makes use of a series of shallow basins, the size and number of which may vary depending upon the capacity for which it is designed. After primary settling to remove suspended solids the sewage is allowed to flow through these ponds for a definite period of time, during this time it is stabilized by bacterial action. Primary treatment usually removes about 45 per cent of the initial sewage BOD (biochemical oxygen demand); treatment in the oxidation ponds usually removes about 80 per cent of the remaining BOD and produces a final effluent with a BOD of about 20 p.p.m. without further treatment.

As stated, oxidation ponds may vary in number and size, depending upon the situation. They may cover more than 30 acres of land, but are always relatively shallow, up to 3 feet deep, to allow for aeration and penetration of sunlight. Operation of the ponds is naturally greatly influenced by seasonal climatic conditions such as temperature, rainfall, hours of sunlight, etc. Where a number of ponds are normally used, say six, it is possible that some of the end ponds may be by-passed during optimal periods of treatment, and/or portions of the effluent may be re-routed to the influent to dilute the initial organic loading of the ponds and supply oxygen where it is most needed.

The breakdown of the organic materials of the sewage in the ponds is accomplished by the action of the aerobic bacteria indigenous to the sewage. The time that the sewage is held in the pond or ponds (detention period) is important because sufficient time must be allowed for this bacterial action to take place. The detention period is dependent upon such factors as the nature of the sewage, volume of sewage, size of the ponds, and the prevailing climatic conditions.

Bacterial breakdown of sewage provides a rich source of nutrient materials and an abundant production of carbon dioxide as end products of bacterial metabolism.

[1] This research was supported in part by a grant from the National Institutes of Health of the U. S. Public Health Service.

Under these conditions rich blooms of unicellular algae appear, converting the CO_2 and nutrients into cellular material in the presence of sunlight and releasing oxygen in their photosynthetic processes.

Papenfuss & Silva (1952) in a systematic study of the algae occurring in oxidation ponds report more than 26 species of algae inhabiting the oxidation ponds of the San Francisco Bay Area and the San Joaquin and Imperial Valleys of California; they also report on the abundance and seasonal incidence of some of these forms. These unicellular plants contribute greatly to the oxygenation of the ponds and undoubtedly are beneficial in supplying oxygen for aerobic bacterial action during the daylight hours; however, they must also compete with the bacteria for oxygen during the night when photosynthetic activity ceases. Moreover, under conditions of long detention (3 to 6 week periods) such as would exist in the latter ponds of a series, these algal cells are potentially unstable organic materials. The organic content of these ponds in the form of algal cell material may be many times greater than that of the sewage present, which is almost completely stabilized.

Ludwig *et al.* (1951), investigating the symbiotic relationship between algae and bacteria in oxidation ponds, report, "The principal work of treatment is accomplished by aerobic bacteria, which oxidize the organic carbon contained in the sewage to carbon dioxide. The algae, through photosynthesis, convert much of this carbon dioxide to algal cell material. Therefore, the pond effluent may contain as much organic material as the sewage entering it . . . 'Old' (Euglena) cells are large and fat, are yellowish in color due to lack of chlorophyll, are reproducing and growing very slowly, produce less oxygen than they respire, and tend to settle out and adhere to bottom surfaces." This algal senescence and settling is constantly occurring in oxidation ponds; the ultimate fate of these cells is opposed to the basic function of the entire purification process, for they add to the organic content of the ponds at a point when the sewage materials have already been stabilized.

Papenfuss & Silva (1952) in their systematic study, also recognized the organic load in oxidation ponds in the form of algae; they report, "The effect of the algal population on the BOD of the sewage oxidation ponds and on that of the stream receiving the final effluent is important. A living cell exerts only a slight BOD, that which is necessary for respiration. When the algal cell dies, however, its body is added to the load of unstable organic matter that exerts a full BOD. A final effluent that has been detained beyond the optimum period will seriously increase the BOD of the receiving stream because of the large number of dead cells."

It appears obvious from this, that any agency operating toward the removal of this algal cell material would be directly beneficial to the operation of sewage oxidation ponds.

Since oxidation ponds are basins hollowed from the earth and have abundant algal plant food available, it is not surprising that certain insect forms would become established there. Qualitative studies undertaken by this research project have revealed about 50 species of insects inhabiting oxidation ponds. By far the most abundant forms present are, in numbers of individuals, members of the dipterous family Tendipedidae (Chironomidae). The larval stages of these flies are aquatic and live in small tubes constructed in the superficial layers of the bottom material. In certain areas during the summer months they may reach a density of 10 to 15 larvae per cubic inch of bottom material. The larvae have been found to occur most abundantly in the zones of recovery in oxidation ponds, i.e., in the zones where algal populations are most dense. Moreover, these larvae are omnivorous and feed directly upon the algae and undoubtedly are the primary agency removing algae from the system.

Weston & Turner (1917), in a study of the digestion of a sewage-filter effluent by a small stream, found great numbers of these flies breeding in the bottom materials and realized that they must be exerting a beneficial influence. They state, "From the omnivorous habits of the larvae, their value as food for fish, and the number of mature insects which leave the water entirely, it is obvious that Chironomus is an important factor in the removal of organic matter." The purpose of the present investigation was to determine how tendipedid affect this algal re-

moval and what influence the larvae have on the BOD during the process of sewage purification under controlled conditions.

METHODS AND PROCEDURE.—Two distinct methods have been employed in the laboratory to investigate the effects of insects on sewage purification; these are continuous cultures and batch cultures. The important difference between these two methods is that of detention period. In continuous cultures a dynamic third dimension is introduced by operating the culture tube, or growth unit, at a certain predetermined detention period, i.e., a given amount of effluent is withdrawn each day and an equal amount of fresh influent is added. In this way daily analyses can be made of the effluent material from the growth unit and a continuous record of the changes taking place traced as the forces involved strive for equilibrium. This technique closely approaches the physical operation of oxidation ponds in the field. Moreover, it involves the most important physical variable determining oxidation pond operation—the length of time available for bacterial action. Also, detention may impose limitations on algal growth by decreasing available nutrients at long detention periods or it may restrict the algal population at short detention periods by rapid removal of cells.

Batch cultures, on the other hand, have a theoretical detention period of infinite time, since nothing is added or removed during the course of operation. These cultures have the advantage of expressing direct relationships in terms of simple time variables. It is difficult, however, to compare directly one set of batch cultures with another, but this can be solved by employing controls with each series and comparing the separate series in terms of the differences expressed by their respective controls.

The continuous growth units used in this investigation consisted of vertically mounted glass tubes 18 inches long and 3 inches in diameter. Each was in a position 6 inches from a single 30-watt daylight-type fluorescent tube from which it received continuous lighting. Water from a constant temperature water bath of 25° C. was passed through a tube running the entire length of the unit for temperature control. Since it was found necessary to employ some kind of mechanism for the purpose of mixing the solution so that algal population counts could be made, another tube was introduced from the top of the unit and extended to within 1 inch of the bottom; air supplied by a small aquarium pump was bubbled into each growth unit through these tubes at the rate of 100 cc per minute. This bubbling invalidated any attempt to make dissolved oxygen determinations, but because of the continuous lighting and presence of algae the dissolved oxygen was always above the saturation point due to photosynthetic oxygenation.

So that the larvae which were to be introduced into these units would have a solid substrate in which to burrow, 0.5 inch of coarse sand previously washed free of soluble materials was placed in the bottom of each. All units were autoclaved before starting a series of tests.

A total volume of 500 ml. of dilute sewage was employed in each test using continuous growth units regardless of the detention period. The substrate used in all tests was a synthetic sewage adopted from a formula developed by L. W. Weinberger (1949). This sewage had the following characteristics: 5 day BOD (20° C.) = 210 p.p.m.; pH = 7.5; total titratable alkalinity = 65 p.p.m.

Twenty species of bacteria from pure cultures and common to normal sewage were used in all the test runs. A single species of alga, *Scenedesmus obliquus*, also from pure culture, was used in these tests to duplicate the algal growth normally found in oxidation ponds. By consistently using the same species of bacteria and the single species of alga, it was hoped to keep the biological variables to a minimum.

To initiate a series of tests a mixture of bacteria was first inoculated into a small amount of synthetic sewage and a film of algae was added. The algae and bacteria were maintained in pure cultures grown on nutrient agar. This mixture was allowed to grow for 3 or 4 days until a dense growth of algae had developed. At this time 100 ml. of synthetic sewage were added to the growth units and 20 ml. of algal-bacterial inoculum were introduced. As the algal growth developed in the growth units, new sewage was added each day until a total volume of 500 ml. and an algal population of about 6×10^6 per ml. was obtained. At this time

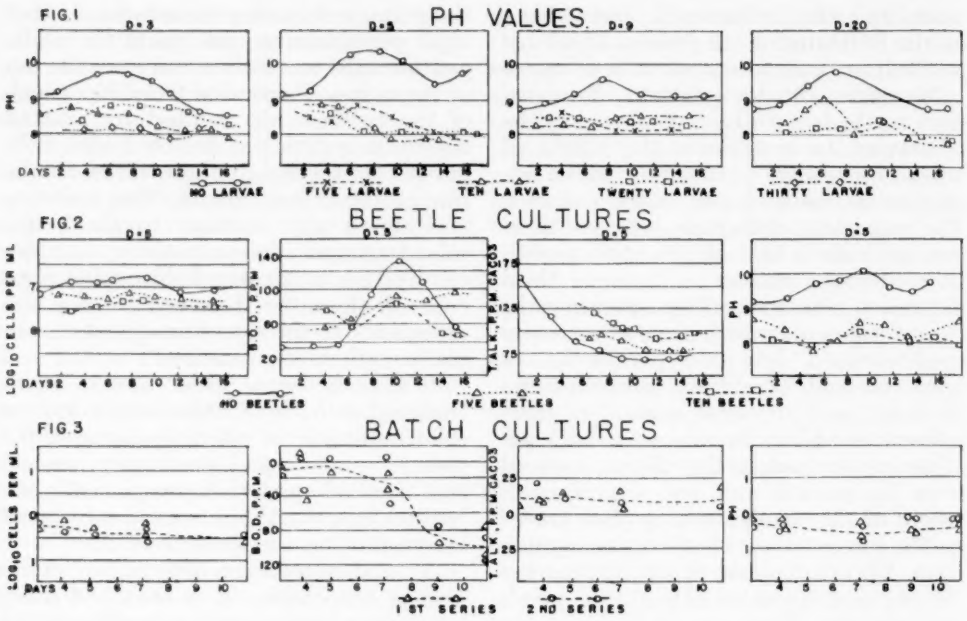

PLATE 1.

a complete transinoculation was made of all six units, larvae were added, and the fixed detention period was started.

Mature larvae of *Glyptotendipes barbipes*, about 2 cm. long, were used throughout the entire investigation. They were first thoroughly washed by repeatedly passing them through successive changes of distilled water to remove any associated protozoans. Individuals which pupated during the course of the tests were removed and replaced immediately by new larvae.

Algal cell counts were made with a haemocytometer. PH readings were made with a Beckman pH meter; total titratable alkalinities were also determined on the pH meter by titrating the sample to a pH of 4.3 with standard acid. Total BOD samples were first heated to 100° C. to kill the algae and then treated in the normal manner according to "Standard Methods" Anon. (1946) technique of the dilution bottle method of determination of BOD.

RESULTS.—*Algal cell populations.*—Plate 2, figure 1, shows graphically the growth curves of the algal populations with respect to detention period and larval action in the continuous growth units. The effects of detention alone upon the control units show that total algal populations increase greatly as the detention period becomes longer. In the shorter period (3 days) the obvious limiting factor is the physical removal of the cells with the large volume of effluent; the cells apparently are unable to multiply rapidly enough to reach higher densities even though nutrients are abundantly available. At the longest detention period (20 days) the total populations are highest. Under these conditions the algae are no longer limited by their rate of removal with the effluent, but are limited by their nutritional requirements. These cells are what might be called "old" cells, for they are multiplying slowly and have a greater tendency to settle out of suspension. The comparative rate of algal multiplication under extremes of detention period can best be appreciated by considering the yield of algal material, i.e., by dividing cell populations by their respective detention period. This shows the algae at the shorter detention to be actually multiplying twice as fast as those of the longer. They are, therefore, the most vigorous and most rapidly assimilating material in the production of algal cell material.

Detention periods of 5 and 9 days express intermediate conditions of algal growth as compared with the two extremes. Theoretically, these algae are existing under what might be considered to approach optimal conditions, since

neither detention period nor available nutrients should be limiting. They are obviously multiplying slower than those of shorter detention periods, but yet they are removed by their effluents rapidly enough so that they do not become "old" cells characteristic of longer detention periods.

Because of the continuous lighting algal populations in the growth units are greater than those which generally occur under field conditions; however, comparable densities have been observed in certain restricted zones in the field, especially along the edges of the ponds.

The effects of the presence of larvae on these algal populations at all detention periods is an obvious one: they reduce algal densities in all cases, even to the point of completely eliminating them, From the evidence it appears that the rate of removal by the larvae is greatly influenced by detention period. At the shorter detentions the rate of removal is apparently considerably increased by the volume of the effluent. This is especially the case after the algal populations have been reduced to a low level beyond which they are unable to maintain themselves further and are very rapidly removed from the system. This influence of detention appears to overshadow the comparative rates of removal by the different numbers of larvae used, for in detention periods up to 9 days a few larvae appear to cause as much reduction in algal populations as do many larvae. At the longest detention period, however, the differential influence of number of larvae is apparent, since each unit volume is in association with the larvae for a longer period of time and therefore reflects their influence more strongly; moreover, the physical influence of detention period is lowest and does not overshadow that of the larvae. The rate of removal at a 20-day detention period is lower than at shorter periods because of the higher initial algal population. Also, the sudden drop in population does not occur, which supports the observation that the higher effluent volumes are mainly responsible for the rapid decline in populations at shorter detention periods, and that the larvae are acting primarily as trigger mechanisms by reducing the algal populations to a point where they can no longer compete with the detention.

Biochemical oxygen demand.—The biochemical oxygen demand test is a measure of organic material as expressed by the amount of oxygen consumed by the bacteriological oxidation of the material at 20° C. for a 5-day period. Since this investigation considered algal cell material as a potential load caused by the ultimate death of the cell, all effluents materials on which BOD determinations were made were first heated to 100° C. to kill the algal cells so that they would be attacked by bacteria and their total BOD would be expressed. This technique gave a common denominator to all such BOD determinations.

Figure 2, plate 2, figures the results of BOD determinations performed on the growth unit effluents. The control units again show the striking influence of detention upon algal population, but these populations are expressed in terms of their organic material (plus that portion of the substrate which had not been stabilized previously by bacteria). In general, however, the BOD's approach the actual growth curves of the algae themselves, reaching higher peaks as the detention becomes longer and algal population higher.

The general effect of the larvae is to lower significantly the BOD's at all detentions. At a detention of 3 days the BOD remains at a relatively high level even though the algal cells have been greatly reduced; this BOD is contributed to the sewage which is only partially stabilized at this short detention, although larval excretory products are undoubtedly also adding to it. The intermediate detentions (5 and 9 days) appear to give the lowest BOD's; they also produce this low level in the shortest time. This coincides with the observation that these intermediate detentions are apparently also optimal for algal growth. However, after the growths have been reduced, the sewage exhibits very low BOD showing that it (plus any larval end products) has had sufficient time to be almost completely oxidized by the bacteria. The BOD's of the control therefore are almost entirely the results of algal cell material. The highest BOD's of the series occur in the growth units operating with the longest detention period, paralleling the highest algal density. The effects of the larvae are very clearly seen to duplicate the curves of associated algal populations and likewise show the quanti-

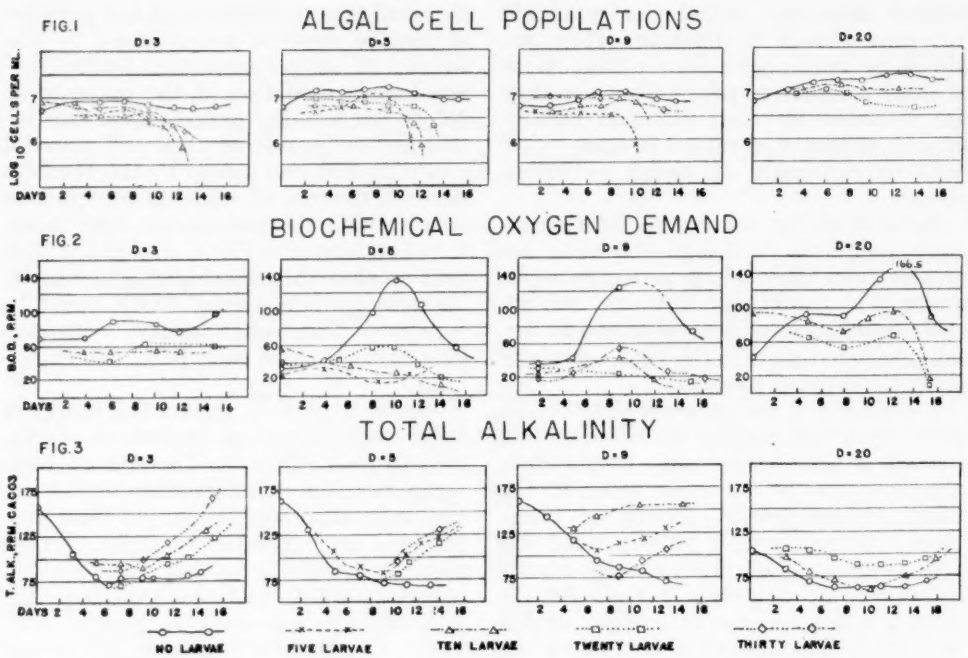

PLATE 2.

tative effects of the larvae. As with the algal populations, the quantitative effects of the larvae do not express themselves at the shorter detentions, but in general follow the algal population curves which are the major contributors to the BOD. However, the various factors involved apparently reach a relatively common low level of equilibrium at the end of each series, for the curves approach a common point.

Alkalinity and pH.—Sewage undergoing bacterial action typically has its pH reduced initially by first-stage oxidation with the production of organic acids; later, the pH rises with the further breakdown of the organic acids. However, when algae are present in the system pH always appears to be well on the basic side. Total titratable alkalinity always runs inversely to algal populations, for the algae abstract carbon from the alkalinity of the sewage through the dissociation of the bicarbonate ions. The released hydroxyl ions plus the removal of carbon dioxide by the algae could well explain the rise in pH. As shown in figure 1, plate 1, pH varies over rather wide limits, for the buffer capacity of the sewage becomes very weak after it has been associated with the algal population, as is indicated by the titratable alkalinity (Figure 3, Plate 2).

The general trend appears to be for the pH values to be higher in the units operating under the shorter detention periods; this is because of the greater amount of bicarbonate alkalinity made available by the higher influent volumes. Therefore, since the algal cells are multiplying more rapidly in these systems and attacking this alkalinity more vigorously, they are releasing the hydroxyl ions in greater amount. Alkalinity at all detentions falls rapidly to very low levels, but because of the different physiological states of the algae at short and long detentions and the differences in the influent volumes, the mechanisms producing this lowered alkalinity are qualitatively different.

When the larvae are present in the continuous growth units the curves for alkalinity and pH are about the same as the control units until the algal populations begin to decline in density. Then there is an immediate increase in the total alkalinity, showing the very marked relationship between algae and alkalinity and the suppressing effect which the algae exert. At detention periods up to 9 days the alkalinity recovers quite rapidly, for the natural increase in alkalinity by the

bacterial oxidation of the sewage is not suppressed by the algal growth, also larval end products, such as NH_4, are adding to the titratable alkalinity. At the longest detention alkalinity does not recover at the end of the test series, for the algal populations are greater and the influent volume is small; however, at the end of the series a slight rise in alkalinity does begin to express itself, paralleling the late decline in algal populations at this detention.

A single series of tests were also run using hydrophilid beetles instead of tendipedid larvae. These beetles are common to oxidation ponds, are omnivorous in their feeding habits, and probably do feed on algae to some extent in their natural environment. It was decided to see what effect they would have on algal populations when the algae were the only source of food available to them. These tests were at a detention of 5 days with increments of five and ten beetles. Figure 2, plate 1, shows the results of these tests.

Apparently the beetles do not very effectively remove algae from suspension, which may be due to their mode of feeding, for the algae would have to settle out in order to be effectively available to them. Since the algae were deliberately kept in suspension in these tests, undoubtedly the cells were not as available to the beetles as they would have been in the field where the natural tendency to settle occurs. The tendipedid larvae, on the other hand, spin webs of silk in forming their tubes and by their undulatory movements within the tubes cause currents of algae to pass through and adhere to the tube. The larvae then literally eat part of the tube to obtain the algae. They also, of course, feed upon algae which have settled from suspension. The beetle, however, did lower the algal population to some degree and correspondingly also lowered the BOD of the substrate. At the end of the test the growth unit with five beetles showed a BOD higher than the control even though the algal population was lower; this could not be explained on the basis of the faecal material added to the solution, for 10 beetles produced a much lower BOD. This test was not duplicated so it is possible that the final BOD determination was for some reason invalid. PH and alkalinity curves for beetles follow similar courses as those which were obtained with larvae, i.e., pH's were consistently lower and total titratable alkalinities slightly higher because of the lower algal populations.

Batch cultures.—A total of 36 separate 100-ml. batch cultures were performed using the synthetic sewage, bacteria and algae as before; 12 of these were controls and the remaining were two separate series in which 10 larvae were present. These tests were run for different lengths of time ranging from 3 to 12 days. The differences expressed between the individual controls and those with larvae present were then plotted by using a base line to represent the controlled conditions and plus and minus values to represent points of departure from these controlled conditions (Figure 3, Plate 1).

In the batch cultures the reduction of BOD caused by the larvae very clearly becomes greater when the larvae are in association with the culture for longer periods of time; at the end of 12 days the differences between the controls and the cultures with larvae are about 100 p.p.m. The reduction in actual cellular material also declines steadily as time increases, reaching its lowest point in 12 days when the series was terminated. At these longer periods the potential BOD of the cells becomes apparent, for although they are no longer multiplying very rapidly they are still increasing their BOD by becoming senescent and accumulating larger quantities of fat.

PH values are consistently lower than those of the control cultures. Total titratable alkalinities, on the other hand, average higher than the controls; this supports observations made on the continuous growth units. The expressed values in the batch cultures are generally of less magnitude than those of the growth units; these differences are obviously due to the influence of detention. The results supplement and support those of the growth unit series, but are not directly comparable because of the important physical-chemical differences of detention period. It is interesting to note that the batch culture results approximate most closely those expressed by the longest detention (20 days); this is to be expected, since detention is exerting its minimal influence at it longest period.

SUMMARY.—The use of oxidation ponds for secondary treatment of sewage is

widely practiced in areas where land is available and the climate is mild.

Natural blooms of algae occur in the ponds and utilize the end products of bacterial oxidation of the sewage in the formation of algal cell material.

Algae are beneficial in providing photosynthetic oxygenation for the aerobic oxidation of the sewage, but may increase the biochemical oxygen demand of the ponds or receiving stream by becoming senescent and adding their cellular materials to the organic load.

Certain species of insects, especially members of the dipterous family Tendipedidae, feed upon algal material and remove it from the system when they pupate and emerge as adults.

Controlled laboratory experiments indicate that these larvae actively remove algae and significantly reduce the biochemical oxygen demand of effluent materials.

The action of the larvae is very closely associated with the influence of detention period, shorter detention periods removing the algae relatively more rapidly than longer periods; however, at too short a detention there is not sufficient time for the bacterial oxidation of the initial sewage organic materials.

Under laboratory conditions the best stabilized effluents were obtained in the shortest time when the detention period was intermediate. At longer detentions the algal density was higher and correspondingly took longer to reduce; also, effluent volume was small and played a minor role in removing cells.

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The Economic Biology of Collembola

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During the interval since Folsom's publication (1933) on this subject and Womersley's discussion (1939) on Australian primitive insects, there have been a number of unpublicized additions to the economic aspects of the Collembola, or springtails. Because of their small size and coloration which usually blends into the surroundings, they are usually overlooked or mistaken for something else, usually fleas, by the uninitiated.

Among the entomological profession, be they taxonomists or economists, the order comprising the primitive insects known as Collembola has always been somewhat neglected. Compared to most other orders, their distribution, habits, and descriptions are relatively obscure, though there have been very notable contributions by Folsom (1933), Guthrie (1903), Maynard (1951), Womersley (1939), Mills (1930, 1934), Bonet (1942, 1945), Schött (1896) and others, not to mention the classic works by Nicolét (1841) and Lubbock (1873) in the 19th century.

Of the approximately 2,200 species described to date, only about 70 are recorded as economically important, but when they are injurious, their numbers make up for lack of variety. Some species occur literally by the millions, e.g., Womersley (1939) reports that the lucerne flea, *Smynthurus viridis* (Linné), may reach populations of 150 million per acre.

Springtails are perhaps the most widely distributed of all insects from the Arctic to the Antarctic wherever moisture conditions are high and decaying vegetable or animal matter may be present. Many species are of cosmopolitan distribution, presumably by water-borne and air-borne dispersion.

Glick (1939) in his very interesting ex-

periences of aerial insect surveys from bases in Louisiana and Mexico, collected springtails at altitudes up to 11,000 feet by means of a net suspended between the wings of a biplane. The following list gives a partial idea of where springtails may be encountered:

Under rocks and boards
In leaves and mulch on the ground
In damp moss
Under bark of dead trees
In rotten wood
In damp soil rich in humus
On the surface of fish ponds, stagnant water, and rain pools
On the surface of snow
In termite tunnels and ants nests
In caves and on surface of underground cisterns
In the gills of mushrooms
In greenhouses on pots, sand, and moss
Under seaweed at the tide marks along seashore
On tidepools and under rocks below tidemark along seashore
In pollen of flowers
In pine cones on the ground
On decaying fruit
On the surface of lichens and damp fungi
Attacking germinating seeds and young seedlings of legumes and other large, fleshy seeds.

As can be seen from the foregoing, most any damp situation can harbor springtails and usually does—even during cold weather. And conversely, arid conditions, either natural or artificial, will eliminate them.

One of the most striking characteristics of the order is the beautiful coloration of individuals, quite often apparent only in living specimens and only under a microscope. Shades of blue, green, yellow, off-white, and purple are predominant and many are of vivid hues of orange, or red with contrasting black or brown markings. Still others are jet black with enamel-white spots. Several families and certain genera contain scaled species—usually iridescent pearly white or metallic gray. Luminous forms of the genera *Anurida*, *Achorutes*, and *Onychiurus* have been reported also. (Barber 1913). Unfortunately, preservation in alcohol or on slides often destroys the original pigmentation so that it becomes necessary to record colors before preservation by viewing through a microscope with transmitted illumination.

Briefly, Collembola may be roughly identified with a hand magnifying glass by several characteristics common to the order. Their small size, generally 3 mm. or less, will differentiate them from most insects occurring with them. One exception is the ground mealy bug, *Rhizoecus falcifer* Kunch.; which is a subterranean species closely resembling springtails of the genera *Onychiurus* and *Morulina*. Various terrestrial spider mites of about the same size may be abundant under similar conditions but are readily distinguished from the insects.

All springtails are wingless in all stages and they may be of two distinct body forms—either subglobular or elongate. For more clarity, the readily observed characteristics of each suborder are outlined below:

SUBGLOBULAR FORMS—SUBORDER SYMPHYPLEONA

1. Always capable of jumping by means of furcula or spring attached to caudal extremities.
2. Usually found in very damp situations.
3. Coloration usually very striking. The most beautiful collembolans belong to this group.
4. Antennae long and distinctly segmented in all but a few species.
5. Body segmentation not evident, bead-like.
6. Body never scaled but usually covered with fine hairs.
7. Size generally less than 2 mm.

ELONGATE FORMS—SUBORDER ARTHROPLEONA

1. Not always capable of jumping. Forms not possessing the spring are sluggish. The jumping species are very active.
2. Found in many situations from very wet to comparatively dry—such as dry ground under leaves and plants.
3. Coloration variable. As would be expected, the sluggish forms without the spring are usually drab and inconspicuous while the jumping forms are generally highly pigmented. Scaled species smooth and shiny.
4. Antennae long or short, usually distinctly segmented. Certain scaled species of the family *Tomoceridae* are notable for their very long tapered and coiled antennae.
5. Body segmentation usually clearly marked. Body form flattened and bulging or cigar shaped, streamlined.
6. Body can be scaled or not. Scaled species always have spring for jumping. Others have numerous types of spines and hairs, warty extremities, or a rough-appearing cuticle.
7. Size from less than 1 mm. to 8 mm. Species of *Tomocerus*, *Neanura* and *Morulina* are the largest of the springtails.

As described by Thomas (1942), springtails have always been a problem to mushroom growers and their depredations to Australian crops during the last 25 years have brought more publicity. Economically, however, the Collembola have been considered relatively innocuous. As workers become more familiar with their appearance and habits, it may be found that damage attributed to other causes may

stem from these seemingly insignificant and vulnerable insects.

Inasmuch as the vegetarian streak in the springtail diet is most important, it is understandable that young, succulent growth in moist surroundings is particularly attractive to certain species. Thus the sphere of potential damage is narrowed and control measures can be gauged accordingly.

Chlordane has proved very effective at 0.5 to 1 pound per acre. However, for best results, the treatment should be to the seed or in transplanting water at same dosages used to control seed-corn maggot, cabbage maggot, symphylids and other soil insects. Aldrin and dieldrin are also extremely effective at dosages recommended for their use on the latter insects.

Nicotine dusts and nicotine bombs have been used with success in mushroom culture where toxic residues must be avoided. TEPP in the latter instance is very effective but should be used before the buttons have formed to avoid burning of the caps. Pyrethrum is not effective nor is DDT too promising. Rotenone is also questionable.

Folsom (1933) lists 43 species of Collembola as being economically important. Womersley (1939) lists 69 of economic importance of which 49 occur in Australia, and he also includes a list of 24 additional species which he believes could become injurious. These references should be consulted for the complete lists and distribution inasmuch as the examples which follow are a selected group from the foregoing papers as well as from other more recent reports.

SELECTED LIST OF INJURIOUS SPECIES BY HABITAT.

Vegetable and Miscellaneous Crops

Hypogastrura (Achorutes) armata (Nic.)—Seeds of beans, peas, sugar beets. Bulbs.
Hypogastrura (Achorutes) longispina (Tullb.)—Bean seeds and seedlings.
Hypogastrura (Achorutes) brevispina (Harvey)—Potato hills, stored celery.
Hypogastrura (Achorutes) purpurascens (Lubb.)—Roots of cabbage seedlings.
Onychiurus fimetarius (L.)—Injures rootlets of carrots, potatoes, beans, peas and fleshy seeds.
Onychiurus ambulans (L.)—Beans, roots of seedlings, peas, cauliflower. Celery leaf stalks, narcissus bulbs.
Entomobrya purpurascens (Packard)—Inside chili peppers, on ripe strawberries on ground.
Entomobrya nivalis (L.)—Damage to hops and berries.
Heteromurus nitidus Templ.—Roots and crowns of strawberry plants.
Proisotoma tennella (Reut.)—Tobacco seedlings.
Orchesella cincta (L.)—Orchid seeds and bulblets.
Smynthurus viridis (L.)—The notorious "Lucerne Flea" or clover springtail which attacks clover seedlings, alfalfa, and other forage crops in Australia.
Bourletiella hortensis (Fitch)—The garden springtail is one of the most widely distributed and injurious species of the Collembola. Has been known to injure seeds and seedlings of beans, beets, cabbage, cantaloupe, carrot, cauliflower, clover, corn, cucumber, horseradish, kale, let tuce, onion, pea, potato, pumpkin, radish, soy bean, spinach, squash, sweet peas, tobacco, tomato, turnip, watermelon, wheat.

Mushroom beds

Hypogastrura (Achorutes) armata (Nic.)
Hypogastrura (Achorutes) manubrialis (Tullb.)
Hypogastrura (Achorutes) maturus (Fols.)
Proisotoma simplex Fols.
Proisotoma thermophila (Axels.)
Lepidocyrtus cyaneus Tullb.
Lepidocyrtus lanuginosus (Gmel.)
Sinella höfti Schaff.
Xenylla humicola (Fab.)

Sugar cane

Folsomia fimetaria (L.) Injures roots—Hawaii
Isotomodes denisi Fols. Hawaii
Isotomurus palustris (Müll.) Louisiana
Pseudosinella violenta (Fols.) Louisiana
Onychiurus armatus (Tullb.) Louisiana

Household invaders

Sira buski Lubb.
Sira nigromaculata Lubb.
Hypogastrura (Achorutes) armata (Nic.)
Entomobrya multifasciata (Tullb.)

SUMMARY.—The Collembola are a comparatively unknown order of insects which occasionally cause considerable damage. Of the approximately 2,200 species described, 70 may be classed as economically important. Collembola or springtails are among the most widely distributed of all insects and many species are cosmopolitan. Dispersion is probably by water and air currents. Springtails are found in many situations where moisture is present along with decaying organic matter. Body pigmentation is usually very striking, though this characteristic is often lost in preservation techniques. All springtails are wingless and the order is divided into two suborders by reason of body shape, the SYMPHYPLEONA or subglobular forms and the ARTHROPLEONA or elongate forms.

Springtails which attack seeds and seedlings, mushrooms, sugar cane and invade houses are listed. Chlordane, dieldrin, aldrin, and TEPP are effective in control, and of the botanical insecticides, nicotine appears to be the only one which is effective.

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Control of Migratory Boll Weevils in the Lower Rio Grande Valley of Texas

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Good field control of the boll weevil, *Anthonomus grandis* Boh., has been reported with various formulations of toxaphene, BHC, aldrin, and dieldrin (Fife *et al.* 1952; Lincoln & Williams 1952; Parencia & Ewing 1953). Gaines and Mistric (1952) in laboratory tests showed that overwintering weevils were easier to kill than those reared from squares. Data secured by these workers also showed that BHC lost 65 per cent of its effectiveness in a 24-hour period following application. Mistric and Gaines (1953), also in laboratory tests, showed that dieldrin was more effective than toxaphene in killing boll weevils under such conditions as low and high temperatures. Because of adverse weather conditions during 1951 and 1952, in the Lower Rio Grande Valley which were favorable to the boll weevil, control of the migratory boll weevil was a major problem. Four experiments were conducted in order to determine the most effective insecticide for the control of migratory boll weevils.

EXPERIMENT 1.—The plots were each 0.5 acre in size. The treatments, shown in table 1, were replicated 4 times and were applied as low volume sprays, using 15 gallons of water per acre. The effectiveness of the various materials was determined by examining 100 squares in each plot for boll weevil injury at the dates shown in table 1.

Few adult boll weevils were observed before July 4. Adult boll weevils started to migrate into the field between July 14 and 18. It is interesting to note that before the boll weevils had started to migrate that aldrin and EPN were as effective as dieldrin in controlling the boll weevil. After migration had started dieldrin at 0.29 pound per acre was more effective than 0.5 pound concentrations of aldrin or EPN.

Table 1.—Control of boll weevil with sprays 1951.

DATE OF		PER CENT SQUARES PUNCTURED			
Spray Application	Infestation Count	0.5 Lb. Aldrin	0.29 Lb. Dieldrin	0.5 Lb. EPN	Untreated
	7-3	10	20	11	9
7-3 7-8					
	7-12	11	8	6	29
7-14					
	7-18	59	65	56	79
7-19 7-23 7-28					
	8-3	61	45	68	88[1]

[1] More than 0.5 acre examined in untreated plots to find 100 squares.

EXPERIMENT 2.—The plots were each 0.1 acre in size. The treatments, shown in table 2, were applied with rotary hand dusters at approximately 20 pounds per acre at 4 or 5 day intervals. Each treatment was replicated 4 times. Light rains fell at 3 or 4 day intervals during the time this experiment was being conducted. Counts were taken of the squares punctured by boll weevils 1 day after the first application and again 3 days after the third and fifth application. In each plot

100 squares were examined. A record was also made of the number of adult boll weevils found on the squares during the last inspection.

Table 2.—Control of boll weevil on small plots dusted with rotary hand dusters. 1952.

Insecticide	Per Cent Squares Punctured Following the Number of Applications as Indicated			Number of Adult Boll Weevils per 100 Squares After 5th Application
	1	3	5	
2-10-40[1]	44	31	82	6
3-10-40[1]	49	43	75	5
20% toxaphene +10% DDT	54	49	88	5
2.5% dieldrin +10% DDT	46	12	40	2
Untreated	53	66	93	14

[1] Per cent of the gamma isomer of BHC-DDT-sulfur, respectively.

The counts taken after the first application showed rather high initial boll weevil damage. Two subsequent applications of the treatments 2-10-40, 3-10-40, and 20 per cent toxaphene plus 10 per cent DDT, reduced the percentage of boll weevil punctures slightly; the untreated plots showed an increase. The 2.5 per cent dieldrin dust with 10 per cent DDT reduced the boll weevil injury from 46 to 12 per cent. At the time of the fourth application adult boll weevils were migrating into the plots. A square examination, made 3 days after the fifth application, showed that 2-10-40, 3-10-40 and the toxaphene-DDT mixture failed to control migratory boll weevils when applied at 4-day intervals. Data presented in table 2 show that the dieldrin-DDT mixture gave control during migration. This is also reflected in the adult boll weevil population. There were fewer adult boll weevils in the dieldrin-treated plots than in either the toxaphene, 3-10-40, or 2-10-40 plots.

Experiment 3.—The cotton field in which this experiment was conducted had been abandoned by the grower because of the heavy boll weevil population. The plots were 0.5 acre in size. Each of the treatments shown in table 3 was replicated 3 times. The insecticides were applied with a tractor-drawn duster at approximately 20 pounds per acre. The first four dust applications were applied early in the morning when the weather was calm and a heavy dew was present. The last application was made at 4 p.m. during an estimated 10-mile wind. Small showers fell 3 to 4 days after each application.

At the time intervals shown in table 3, 6 inches of terminal of each of 50 plants in each plot were examined for adult boll weevils. One week after the final application, 10 leaves were pulled at random from each plot and the number of cotton aphids per square inch were recorded. The most aphids were found on the untreated plots and the plots treated with the calcium arsenate-sulphur mixture.

Data given in table 3 indicate that the dieldrin-DDT mixture and 3-10-40 were more effective than 20 per cent toxaphene or the mixture of calcium arsenate-sulphur in reducing severe infestations of the adult boll weevil. The dieldrin-DDT mixture was more effective than the 3-10-40 dust. Dieldrin gave a quicker kill of weevils than 3-10-40 following the third application. Both the dieldrin-DDT

Table 3.—Effectiveness of insecticides against adult boll weevils. 1952.

Date of Application	Insect Count[1]	Average No. Adult Boll Weevils on 50 Plant Terminals				
		3-10-40	2.5 Per cent Dieldrin+ 10 Per Cent DDT	20 Per Cent Toxaphene	50 Per Cent Calcium Arsenate+ Sulphur	Untreated
6-29	2	7.3	5.7	28.0	30.3	50.3
	3	12.7	6.7	30.0	30.0	52.7
7-3	Rained 24 hours after application					
7-5	0.42	12.7	1.0	10.0	14.3	28.0
	1	6.3	2.3	17.0	15.0	40.3
	3	18.3	12.0	25.7	31.7	42.7
7-9	1	10.3	5.3	17.7	29.0	38.9
	3	24.0	16.3	32.3	41.0	48.7
7-12	Applied in a 10 mile wind at 4 p.m.					
	1	11.0	9.0	18.3	26.7	38.0
	3	24.3	17.0	31.3	35.3	43.3

[1] Days following application of insecticides.

Table 4.—Control of adult boll weevils with low volume sprays. 1952.

Insecticide per Acre (Lbs.)	Boll Weevils per 100 Squares 24 Hours After Treatment	
	Number	Per Cent Reduction
0.05 endrin	50	6
0.1 endrin	43	19
0.2 endrin	21	60
0.4 endrin	26	51
3.0 toxaphene	41	23
0.75 EPN	45	15
Untreated	53	—

and the 3-10-40 dust gave excellent control of the boll weevil for the first 2 days after application, but the population of adult weevils increased greatly on the third and fourth days on plots treated with both materials. These data indicate the necessity of shortening the recommended interval of 4 to 5 days between applications at the time of boll weevil migration to 3 or 4 days.

A few growers had more acreage than could be treated during ideal dusting conditions. As a result, a considerable acreage was dusted by both ground and air equipment when the wind was approximating 10 miles per hour. Results given in table 3 show that insecticides applied during windy weather were not as effective as applications applied early in the morning when the weather is calm. In certain instances, failure to obtain boll weevil control with insecticides was due to ineffective applications made during windy periods.

EXPERIMENT 4.—The cotton field in which this experiment was conducted had been abandoned by the grower because of a heavy boll weevil population. The plots were each 0.5 acre in size and each of the treatments was replicated 3 times. The insecticides were applied as low volume sprays in 15 gallons of water per acre and 24 hours after the applications were made 100 squares were examined in each plot for adult boll weevils. The data given in table 4 show that endrin, at 0.2 or 0.4 pound per acre, reduced the adult boll weevil population greatly and that toxaphene at 3 pounds or EPN at 0.75 pound per acre had little effect on the adult boll weevil population.

SUMMARY.—Dust mixtures of 2.5 per cent dieldrin with 10 per cent DDT and 3-10-40 were more effective than 20 per cent toxaphene or 50 per cent calcium arsenate-sulphur in controlling migratory boll weevils. Dieldrin was slightly more effective than the 3-10-40 dust.

As a spray dieldrin at 0.29 pounds per acre was more effective than 0.5 pound of aldrin or EPN in controlling migratory boll weevils. Endrin at 0.2 pound per acre was also more effective than toxaphene at 3 pounds or EPN at 0.75 pound against the adult boll weevil.

During boll weevil migration the intervals between applications should be shortened to 3 or 4 days.

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Treatment of Bean Seed for the Control of the Seed-Corn Maggot[1]

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The seed-corn maggot, *Hylemya cilicrura* (Rond.), has been an important pest of lima beans in southern California for many years. Damage by this insect has increased in recent years, apparently as an indirect result of the use of new chemical methods for the control of wireworms. Wireworms have been found by Stone (1953) to be predacious on the seed-corn maggot. The control of wireworms led to the planting of winter crops previously avoided to discourage the development of wireworms. These crops added decaying plant matter to the soil and have thereby favored the development of the seed-corn maggot. The increased planting of alfalfa and of vegetables for freezing has also favored seed-corn maggots.

Studies were begun in southern California in 1948 to find methods of treating bean seed to prevent damage by the seed-corn maggot. No satisfactory insecticides for the control of this pest were known at that time. Turner (1945) was unsuccessful in obtaining control of the seed-corn maggot by treating lima bean seed with DDT in combination with a fungicide. Ristich & Schwardt (1949) concluded that treatments of the seed of red kidney beans with chlordane or BHC (benzene hexachloride) gave little promise as a control measure. However, Dills & Odlund (1949) reported encouraging results from the use of methoxychlor. Lange *et al.* (1950) found that treating lima bean seed with lindane for wireworm control may give partial protection against the seed-corn maggot. Later Lange *et al.* (1951) reported partial control with lindane, aldrin, dieldrin, and chlordane combined with a fungicide.

In preliminary experiments during 1948 and 1949 promising results were obtained by treating bean seed with chlordane, aldrin, or lindane, mixed with a fungicide. However, such treatments frequently caused injury to the sprouting seed, with a consequent reduction in the stand. Apparently this injury was associated with soil-borne fungus diseases, soil alkalinity, moisture conditions, and the common use of ethylene dibromide as a soil fumigant, before planting, for the control of wireworms and nematodes. The experiments conducted in 1950, 1951, and 1952 are reported herein.

FIG. 1.—Self-propelled bean planter used in experimental treating of lima bean seed for control of the seed-corn maggot.

METHODS.—Usually the plots consisted of single rows at least 100 feet long, and were arranged in five randomized blocks. In 1950 planting was done with hand planters and with large 8-row planters, but irregular planting rates with these large planters led to the construction of a self-propelled single-row planter for use in 1951 (Fig. 1). It has a pickup wheel that drops the seeds so that each 100 feet of row receives the same number, approximately 240 for Ventura beans and 300 for

[1] This work was done under the direction of Roy E. Campbell at Alhambra, Calif., and in cooperation with the agricultural commissioners and Agricultural Extension Service of Orange and Los Angeles counties. Valuable assistance was given by Jack Gould, field representative of the California Lima Bean Growers' Association, and by A. H. Holland and his assistants and Paul Moore, assistant farm advisors of Orange and Los Angeles counties, respectively. The Dow Chemical Company arranged for the ethylene dibromide fumigation, and the Smeltzer Warehouse of the Lima Bean Growers' Association and the California Consumers' Corporation furnished seed samples.

Fordhooks. The lima beans were planted at the rate of 100 to 120 pounds per acre.

The lima bean seed was of the same quality and varieties as were used by farmers in the area, but was re-sorted and blended carefully before being treated. The large lima variety Ventura and Fordhook variety No. 242 were used. Germination ranged from 92 to 95 per cent.

The insecticides were either applied as a seed coating prior to planting or sprayed onto the seeds as they were dropped from the bean planter. For seed coating, the insecticides were mixed with the fungicide in a laboratory sifter-mixer. This combination was then mixed with the seed either dry or after it had been made into a water slurry. The slurries were prepared from wettable insecticide powders and specially prepared fungicide preparations containing adhesives.

A device for spraying seed (Elmore 1950) was used on regular field and hand planters in 1950 and on a self-propelled planter in 1951 and 1952. A hand sprayer with pressure gauge, first used in 1951, delivered the required quantity of spray—16 gallons per acre except in the Conley field (Table 5), where 10.5 gallons were used. Fungicide-coated seed was always used when insecticide sprays were applied in the row.

MATERIALS.—The insecticide preparations most used in the experiments were 50-per cent wettable powders of aldrin, chlordane, heptachlor, lindane, and methoxychlor. Tests were also made of 25- and 75-per cent aldrin and lindane and 75-per cent dieldrin wettable powders, an emulsifiable concentrate containing 2 pounds of chlordane per quart, and an emulsifiable concentrate containing 12 pounds of ethylene dibromide per gallon.

The fungicides were a 75-per cent thiram wettable powder and Spergon, a proprietary preparation that contains 95 per cent of tetrachloroparabenzoquinone. The manufacturers of thiram recommend using it as a slurry for the treatment of bean seed. Spergon may also be used as a slurry, but it is most commonly used as a dry powder.

In most of the seed coatings 0.25 to 0.5 ounce of the insecticide was applied per 100 pounds of seed. Usually 3.5 ounces of the fungicide concentrate was used in dry seed coatings and 2.5 ounces in slurry treatments. In sprays the dosage of toxicant was 1.25 ounces per acre, except for ethylene dibromide, which was used at 2 to 6 pounds per acre. For convenience in comparing seed coatings with sprays, the dosages have been expressed as ounces per acre, on the basis of 100 pounds of seed per acre.

EXPERIMENTS IN 1950.—The experiments in 1950 were conducted in areas where replanting had been necessary because of injury by seed coatings. In the first experiment the seed-corn maggot was controlled with chlordane sprays at 6.4 ounces of chlordane per acre in a suspension and in an emulsion. Control was also obtained in dry seed coatings with aldrin and lindane at 0.5 ounce plus Spergon concentrate at 4 ounces per 100 pounds of seed, or per acre. In the sprayed plots and one set of check plots the seed was coated with Spergon at the same dosage. The sprays increased the plant stand as compared with the Spergon check, whereas the dry seed coatings with aldrin and lindane reduced it. Spergon alone increased the plant stand over the untreated check.

In another field chlordane emulsion spray was compared with dry seed coating with various materials, as shown in table 1. All the materials except methoxychlor were effective as seed coatings, but dieldrin and lindane caused reductions in plant stand below that sprayed with chlordane. Injury was more noticeable in wet soil.

EXPERIMENTS IN 1951.—In 1951 lindane, dieldrin, and heptachlor were used

Table 1.—Effectiveness of dry seed coatings with various insecticides as compared with chlordane emulsion spray for control of the seed-corn maggot on Fordhook lima beans. All seeds coated with Spergon. Dady field, 1950.

TREATMENT (OUNCES PER ACRE)	NUMBER OF PLANTS PER 100 FEET OF ROW	
	Total	Number Injured
Spray emulsion, chlordane 6.4	227	3.3
Seed coating (dry):		
Chlordane 0.5	212	2.2
Aldrin 0.5	191	0.8
Dieldrin 0.5	177	0.9
Lindane 0.5	167	1.3
Methoxychlor 0.5	213	16.9
Check(Spergon alone)	243	21.0
Difference required for significance at odds of 19:1	44	1.4

Table 2.—Stand of lima bean plants and injury by the seed-corn maggot following seed-coating treatments in four fields, 1951.

Materials (Ounces per Acre)	Number of Plants per 100 Feet of Row					
	Field				All Fields	Injured Plants
	A	B	C	D		
Dry seed coating:						
Spergon 3.5 plus—						
Lindane 0.25	206	239	—	—	223	1.8
0.5	155	176	—	—	165	.7
Dieldrin 0.25	167	214	—	—	190	1.2
0.5	138	190	—	—	164	.8
Heptachlor 0.25	170	209	—	—	190	1.6
0.5	134	147	—	—	140	.6
Check (no insecticide)	258	214	—	—	236	31.5
Slurry seed coating:						
Spergon 2.5 plus—						
Lindane 0.25	—	—	220	126	173	0
0.5	—	—	181	96	138	0
Dieldrin 0.25	—	—	187	107	147	0
0.5	—	—	163	110	136	0
Heptachlor 0.25	—	—	165	125	145	0
0.5	—	—	162	89	126	.05
Check (no insecticide)	—	—	200	184	192	4.6
Thiram (75%) 2.5 plus—						
Lindane 0.25	205	261	223	157	212	0.2
0.5	196	215	228	157	199	.1
Dieldrin 0.25	210	241	230	173	214	.1
0.5	209	261	242	183	224	.2
Heptachlor 0.25	223	266	235	193	224	.1
0.5	184	239	225	168	204	.1
Check (no insecticide)	288	235	204	210	234	18.2
Difference required for significance at odds of 19:1	48	36	22	20	—	—

in four fields at 0.25 and 0.5 ounce per acre, mixed with Spergon or thiram. Two fields (A and B) were planted to Fordhook beans and two (C and D) to Ventura limas. Dry coating with Spergon was used on the Fordhooks and slurry with Spergon on the Venturas, in comparison with thiram slurry combinations in all four fields.

Insecticides mixed with thiram resulted in better and more nearly uniform plant stands than the same materials mixed with Spergon. When mixed with dry Spergon, 0.5 ounce of insecticide was more effective than 0.25 ounce against the seed-corn maggot, but the 0.25-ounce treatments resulted in significantly more plants per 100 feet. This dosage was probably less effective against the seed-corn maggot because of poor adhesiveness and uneven coating of the seed. Furthermore, uneven distribution of the higher dosage may have resulted in insecticide injury, particularly when lindane was used. When the insecticides were applied as slurries, the difference between the two dosages in effect on plant stand was less pronounced and the lower dosage was as effective as the higher one. Dieldrin and heptachlor appeared to be less injurious to bean seed than lindane (Table 2.)

Spray treatments were again compared with seed coatings in two lima bean fields. In the Conley field, in which thiram-insecticide combinations were used, lindane, aldrin, dieldrin, and heptachlor were compared as sprays with the same insecticides used as seed coatings. Chlordane was used only as a spray.

Spray treatments produced better plant stands than seed coatings, probably owing to the addition of moisture, as indicated by the increase in plant stand with water spray over no spray. There was no significant difference between spray dosages of 10.5 and 16 gallons per acre when equal amounts of insecticide were applied. There were slightly better plant stands following the dieldrin and lindane treatments than in the others (Table 3).

In the Pelous field spray treatments

Table 3.—Effectiveness against the seed-corn maggot of treatment of Ventura lima bean seed with various insecticides at 1.6 ounces per acre in sprays, and at 0.5 ounce in slurry seed coatings. All seeds were coated with thiram. Conley field, 1951.

Insecticide	Plants per 100 Feet of Row: Spray per Acre 10.5 gal.	Spray per Acre 16 gal.	Seed Coating 0.5 oz. per 100 pounds of seed	Per Cent Injured by Maggots
Aldrin	202	192	166	0
Dieldrin	208	201	181	0.4
Heptachlor	202	191	145	.1
Lindane	196	201	175	0
Chlordane[1]	182	184	—	.2
Checks:				
Water spray only	—	152	—	23
No spray	—	—	73	65
Difference required for significance at odds of 19:1	15	15	20	

[1] Dosage 6.4 ounces per acre.

were made in soil high in fresh organic matter. Sprays were applied to seed coated with dry Spergon or thiram slurry at the time of planting. The spray treatments produced an average of 262 plants from seeds coated with thiram slurry as compared with 208 plants from seeds coated with dry Spergon. Water spray with no insecticide on thiram-coated seed produced a better stand than thiram-coated seed alone. The seed-corn maggot infestation, although causing up to 13 per cent injury in check plots, was satisfactorily reduced by the sprays on thiram-coated seed and by the insecticide-thiram slurry seed coating. The dieldrin and lindane treatments produced better plant stands than did the aldrin treatment when Spergon was used, but there was no difference in the effect of the insecticides when thiram was used (Table 4).

EXPERIMENTS IN 1952.—In 1952 comparisons were made of insecticide sprays on thiram-coated seed and treatments with slurries containing the insecticide mixed with thiram. Five replicates were made in each of two fields. As shown in table 5, seed-corn maggots were abundant in both fields, but all treatments that included one of the insecticides prevented injury to the seed (Fig. 2). Lindane slurry, however, reduced the stand of plants in one field.

SEED TREATMENTS WITH ETHYLENE DIBROMIDE.—In 1950 an experiment was conducted to test the usefulness of ethylene dibromide alone and mixed with insecticides in sprays applied at 16 gallons per acre for seed-corn maggot control. All the seeds had been treated with Spergon slurry at 4 ounces per acre. Maggot control was satisfactory with all treatments except Spergon alone but, as shown in table 6, the plant stand decreased as the dosage of ethylene dibromide was increased. However, ethylene dibromide alone at 6 pounds per acre caused no plant injury.

Table 4.—Effectiveness against the seed-corn maggot of spray treatments on Fordhook bean seed coated with two fungicides. Pelous field, 1951.

Insecticide Treatment (Ounces per Acre)	Plants per 100 Feet of Row: Dry Spergon, 3.5 Ounces	Thiram Concentrate, 2.5 Ounces in Slurry	Per Cent Injured by Maggots
Suspension sprays:			
Aldrin 1.5	198	263	0.05
Dieldrin 1.5	219	262	.05
Heptachlor 1.5	214	271	0
Emulsion spray:			
Chlordane 6.4	202	255	0
Check:			
With water spray	—	265	8.8
Without spray	234	248	13.4
Dry seed coating			
Lindane 0.375	218	—	0.3
Difference required for significance at odds of 19:1	17	17	9.0

DAMAGE BY ETHYLENE DIBROMIDE FUMIGATION.—In 1952 an experiment with 5 replicates on lima bean seed treat-

Table 5.—Effectiveness against the seed-corn maggot of insecticides applied as sprays and slurries to Fordhook bean seed. Thiram concentrate was applied at 2 ounces per 100 pounds as a slurry to all seeds. 1952.

Materials (Ounces per Acre)	Plants per 100 Feet of Row: Field A Total	Field A Injured	Field B Total	Field B Injured
Spray:				
Aldrin 1.25	269	1	238	1
Dieldrin 1.25	280	1	234	0.5
Heptachlor 1.25	279	1	243	0.5
Lindane 1.25	274	0.2	226	1
Check (water spray)	267	100	266	78
Slurry:				
Aldrin 0.25	261	0.5	228	0
Dieldrin 0.25	265	0	223	0.5
Heptachlor 0.25	254	0.5	223	0.2
Lindane 0.25	201	0	221	0.5
Check (no insecticide)	257	116	249	135
Difference required for significance at odds of 19:1	42	—	19	—

FIG. 2.—Increase in bean plant stand due to seed-corn maggot control. Rows 3 and 7 received insecticide spray and row 10 insecticide seed coating. Eight rows to the right were untreated.

ments with insecticides was superimposed on an experiment with 5 replicates on ethylene dibromide fumigation of the soil.

After 12 days seeds given various treatments with insecticides were planted across the fumigation plots. As shown in table 7, the fumigation caused a general reduction in plant stand, but this reduction was as great where the seeds were not treated with insecticides or fungicides as where the seeds were treated. Slurry-coated seeds emerged better than spray-treated seeds.

SUMMARY.—Experiments on the concontrol of the seed-corn maggot, *Hylemya cilicrura* (Rond.), on lima beans were started in 1948 as a result of an increase in abundance due to wireworm control and a change in crop rotation. A method of applying an insecticide spray in the row on fungicide-treated seed was developed first, but seed coating with the same insecticides mixed with a fungicide was found to be just as effective and much simpler. Aldrin, dieldrin, heptachlor, and lindane were the most effective materials at 1.25 ounces per acre when applied as sprays, and at 0.25 ounce per acre as slurry seed coatings. Chlordane was effective in both treatments, but considerably more of it was required. Methoxychlor was not effective.

The reduction in plant stand caused by fumigation of the soil with ethylene dibromide 12 days before the planting of lime bean seed was not affected by seed treatments.

Table 6.—Number of Fordhook bean plants per 100 feet of row from seed treated with dry Spergon before being sprayed with insecticides mixed with ethylene dibromide. H. Moore field, 1950.

Insecticide (Ounces per Acre)	Ethylene Dibromide (Pounds per Acre)			
	0	2	4	6
Chlordane 6.5	138	138	137	114
Aldrin 2	134	147	140	115
Lindane 2	153	—	134	—
Check (no insecticide)	134	—	—	142
Difference required for significance at odds of 19:1	9	9	9	9

Table 7.—Effect of soil fumigation with 3 gallons of 85 per cent ethylene dibromide per acre 12 days prior to planting of seed treated with thiram and various insecticides. H. Moore field, 1952. All seed slurry-treated with 2 ounces of 75 per cent thiram concentrate per acre.

Insecticide (Ounces per Acre)	Plants per 100 Feet of Row		Per Cent Reduction Due to Fumigation[1]
	Fumigation	No Fumigation	
Seed coating with thiram slurry			
Aldrin 0.5	267	302	12
Dieldrin 0.5	270	300	12
Heptachlor 0.5	277	304	9
Lindane 0.5	284	303	6
Checks: Thiram (75%) 2	261	303	14
Spergon 2.5	244	284	14
Spray after thiram slurry			
Aldrin 1.25	244	274	11
Dieldrin 1.25	234	273	14
Heptachlor 1.25	210	245	14
Lindane 1.25	217	264	18
Check (water spray)	218	267	18
Difference required for significance at odds of 19:1	18.4	18.4	—[2]

[1] A reduction of 6.7 per cent is significant at odds of 19:1.
[2] Differences not significant according to the F test.

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Comparative Toxicities of Certain Organic Insecticides to Resistant and Non-Resistant Strains of the German Cockroach, *Blattella germanica* (L.)

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It appears that Smith (1897) was the first to notice resistance to insecticides of insects. However, the first publication of insect resistance generally is attributed to Melander (1914). Sporadic reports of insect resistance continued until World War II. With the widespread use of organic insecticides following the end of World War II the reports on resistance to insecticides increased. A review was published by Babers (1949), covering the literature up to the fall of 1948, concerning the resistance of insects. The reports that chemicals failed to control certain insects and the potential significance attached thereto apparently was not universally recognized at this time. In the period following Babers' report these failures received great publicity in scientific publications and in the press.

In 1951 another review of the literature concerning insect resistance was published (Babers & Pratt 1951). This report contained no references of resistance to insecticides by the German cockroach. Since then, as far as the writers have been able to determine, there have been four reported cases of resistance of the insect. These reports were made by Grayson (1951, 1953), Cockran *et al.* (1952), and Heal *et al.* (1953). These reports were concerned with three resistant strains of the German cockroach. Grayson (1951, 1953) reported on a DDT and benzene hexachloride-resistant strain; Cochran *et al.* (1952) reported on the same DDT-resistant strain as Grayson; and Heal *et al.* (1953) reported on a strain of cockroaches from Corpus Christi, Texas, resistant to chlordane.

This research was directed toward determining the degree of resistance of the above mentioned DDT and chlordane-resistant strains.

MATERIALS AND METHODS.—The cockroaches used in this experiment were *Blattella germanica* (L.). Two resistant strains of this species were compared to a normal strain to determine the degree of resistance. The resistant strains were designated as DDT-resistant and chlordane-resistant strains. These terms are misleading in that the strains were also resistant to chemicals other than those named. However, the terms are convenient and as such will be used throughout the article.

The DDT-resistant strain was obtained from Dr. James McD. Grayson of the Virginia Agricultural Experiment Station. Resistance of this strain was brought about by exposure at periodic intervals under controlled laboratory conditions (Grayson 1951, 1953).

The chlordane-resistant strain was obtained from Mr. Frank H. Babers of the Bureau of Entomology and Plant Quarantine, Beltsville, Maryland. In March

FIG. 1.—Topical application technique in operation.

1952 pest control operators reported difficulty in controlling German roaches with chlordane (Heal *et al.* 1953). It was from some of these cockroaches that Mr. Babers reared a chlordane-resistant culture.

The toxicity tests in this paper were performed on adult female roaches approximately 6 weeks of age. Topical application of the insecticide in solution was used as the testing technique. A measured quantity of the insecticide solution was applied between the prothoracic coxae of the insect. Materials used in this technique consisted of a one-fourth cubic centimeter syringe, a micrometer caliper head, a wooden mount for the syringe and micrometer, and glass tubing. The syringe and micrometer were so mounted that the plunger could be driven forward by manual operation of the micrometer. Turning the micrometer 0.005 inch delivered 0.94 microliter. The glass tubing (Pyrex) was fitted to the tip of the syringe, drawn to a fine flared tip, and bent downward at a 90° angle. It was found that the adhesion between the solvent used and the glass tip was such that the solution tended to roll up the sides of the tip. In order to overcome this the tip was flared thus preventing the solution from creeping up the sides. Except for the modification of the glass tip the method used was the same as that described by March & Metcalf (1949).

Carbon dioxide, as an anesthetic, was used to facilitate handling of the roaches while employing the technique. Rather than handle each cockroach individually during the application, 10 specimens were anesthetized and placed in a row on a small metal plate. Touching each cockroach consecutively to the glass tip, after turning the micrometer the prescribed number of turns, greatly speeded up the technique. This arrangement is shown in figure 1. Following the application of the insecticide the cockroaches were placed in a petri dish and then put into a Cenco refrigerated incubator set at 25° C. Mortality counts were taken at the end of 48 hours. All rearing and testing was done at a temperature of 25°±2° C. It is of utmost importance that constant temperatures be maintained due to the varying effects that different temperatures have upon the toxic action of insecticides (Guthrie 1950).

At least three levels of concentration were used for each probit line. Each level of concentration was replicated 3 times and 10 cockroaches were used for each replicate. The replicates for each level of concentration were averaged and plotted on log-probit paper. The LD_{50} for each toxicant was calculated by this method.

The technique of topical application requires that the toxicant be applied in the form of a solution or stable emulsion. Mixtures of several solvents were tried. It was found that the solvent most useful in this work consisted of a solution composed of 80 per cent Deo-Base and 20 per cent acetone. This solution was adequate for all toxicants tested. By varying the concentration, different amounts of the toxicant were applied while using the same amount of solvent.

Toxicants applied were prepared from unformulated samples of chlordane and dieldrin from Velsicol Corporation, allethrin and MGK-264 from McLaughlin Gormley King, and DDT and *Diazinon* (0,0-diethyl-0-[2-isopropyl-4-methyl-pyrimidyl (6)] thiophosphate) from Geigy Company, Inc. All formulations were based on the per cent concentration of actual toxicant. The allethrin formulation, in addition to the solvent, contained the synergist MGK-264 used in a ratio of 9 parts MGK-264 to 1 part allethrin. In computing the dosage of this mixture only the allethrin was calculated as the toxicant.

RESULTS AND DISCUSSION.—The summarized toxicities, in terms of LD_{50}'s, of

the organic insecticides tested to the three strains of female German cockroaches are presented in table 1. This table also includes the approximate degree of resistance exhibited by the two resistant strains. Resistance, in some degree, is displayed by both strains to all the toxicants tested, including synergized allethrin.

Table 1.—The LD_{50} dosages of various insecticides to normal and two resistant strains of German cockroaches[1] and the degree of resistance shown to each insecticide.

		DDT-RESISTANT		CHLORDANE-RESISTANT	
COMPOUND	NORMAL STRAIN LD_{50}[2]	LD_{50}	Degree of Resistance	LD_{50}	Degree of Resistance
DDT	13.5	25.0	1.9	19.0	1.4
Chlordane	2.3	4.1	1.8	250.0	108.6
Dieldrin	0.5	0.62	1.2	34.0	68.0
Diazinon	0.33	0.78	2.4	0.4	1.2
Synergized allethrin[3]	0.76	1.3	1.7	1.0	1.3

[1] Based on 48-hour mortalities from topical applications.
[2] LD_{50} dosage in micrograms actual toxicant per female roach.
[3] LD_{50} based on amount of allethrin only.

The resistance to DDT shown by the DDT-resistant strain of cockroaches is very slight. Grayson (1951) reported on the resistance of this same strain and stated that 14.3 times as much DDT was needed for an LD_{50} as for the normal strain. It is felt that the difference between the reported degree of resistance and that shown by these experiments is due almost entirely to the period of time between exposure to DDT and the time at which the toxicity tests were conducted. Grayson conducted his tests on individuals of the first generation following seven generations' exposure to DDT. The experiments in this paper on the DDT-resistant strain were performed on specimens which had passed through approximately nine more generations, during which time they were not exposed to any insecticide. Presumably, the loss of resistance, exhibited by the DDT-resistant strain, indicates that considerable reversion has taken place. Work from other laboratories has shown that insects tend to revert toward their normal susceptibility when they are kept from the insecticides to which they are resistant.

Several theories in regard to reversion have been advanced. One theory, which seems quite plausible, is that the genes for insecticide resistance must somehow be detrimental (Crow 1952). Reports of reduced fecundity, inviability of eggs, and longer life cycle in resistant strains seem to confirm this. If the genes for resistance are detrimental, then it seems likely that if the pressure of an insecticide were removed reversion would result.

A high degree of resistance to chlordane and dieldrin was exhibited by the chlordane-resistant strain. Resistance to the other toxicants was light. The resistance to chlordane was over 100-fold. Heal *et al.* (1953) reported on this same strain (called Corpus Christi strain by them) and stated that the resistance to chlordane was over 100 times that of normal roaches. Heal conducted his tests on individuals of the second and third generation distant from field collected material. The experiments of this paper were performed on cockroaches which had passed through approximately nine generations without exposure to insecticides. In contrast to the DDT-resistant strain it is apparent that little or no reversion has taken place with the chlordane-resistant strain.

Perhaps this failure of the chlordane-resistant strain to revert as did the DDT-resistant strain was due to its high initial resistance. It is possible that this strain was subjected to its specific toxicant (chlordane) for a longer period of time and that the toxicant was present throughout the life cycle of these insects. Thus, selection took place over a longer period of time and was more severe, therefore the chlordane-resistant strain was possibly more homozygous for resistance than the DDT-resistant strain. The DDT-resistant strain, having a greater degree of heterogeneity, would therefore revert more quickly. However, this is only conjecture as it is not known whether the more stable resistant strains are more homozygous than the less stable resistant strains (Crow 1952).

One compound, *Diazinon*, deserves special mention. This is a new compound which is said to be an effective insecticide for controlling house flies which show resistance to the chlorinated hydrocarbon insecticides. The data in this paper indicate that this phenomenon apparently does not carry over with respect to resistant cockroaches as the resistant strains of cockroaches exhibited resistance to *Diazinon*. However, the compound seems to be quite effective against normal strains

of cockroaches, being more toxic than chlordane or dieldrin.

SUMMARY.—Two strains of resistant German cockroaches were compared with a normal strain of the same species to determine the degree of resistance to five organic insecticides. The resistant strains were designated as DDT-resistant and chlordane-resistant.

Toxicity tests were conducted with a topical application method. By the use of this technique micro quantities of insecticides in solution, approximately one microliter, were applied between the prothoracic coxae of the anesthetized test insect. The insecticides tested were DDT, chlordane, dieldrin, *Diazinon*, and synergized allethrin.

The per cent mortality obtained at the end of 48 hours was used to compute the probit curves from which LD_{50}'s were calculated. The degree of resistance was calculated by comparing the LD_{50}'s of the resistant strains with those of a normal strain.

Both strains of insects exhibited resistance in some degree to all toxicants tested. The degree of resistance exhibited by the DDT-resistant strain was quite low in all cases. The chlordane-resistant strain was highly resistant to chlordane and dieldrin but was only slightly resistant to the other toxicants.

Possible reasons for these differences between the resistant strains are advanced.

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Chlordane, Dieldrin, Aldrin, and Heptachlor for Control of the Argentine Ant in California Citrus Orchards[1,2]

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The Argentine ant, *Iridomyrmex humilis* Mayr, in the United States was first recorded from New Orleans in 1891 (Newell 1908, Foster 1908). The ant spread rapidly in the southern states and soon became a household as well as an agricultural pest. It was first recorded from California in 1905 by Dr. E. S. G. Titus (Woglum & Borden 1921, Flanders 1943), who collected specimens at Ontario, San Bernardino County. From this infestation the Argentine ant spread rapidly throughout southern California. It was not long until it was recognized that the Argentine ant interfered with the activities of parasites and predators of scale and mealybugs (Smith 1917, Woglum 1919), and that some means of controlling the ant was desirable.

Recent emphasis on the biological control of many of the scale and mealybug pests of citrus (Flanders 1943, 1945, 1951; DeBach *et al.* 1951) has created a need for an ant-control program which can be easily applied and maintained. Many of the control methods used heretofore, such as tanglefoot bands (Woglum 1917) and poison baits (Ryan 1926, Woglum 1942), have not proved entirely satisfactory or economically feasible.

The present investigation was conducted for the purpose of comparing the effectiveness of the following insecticides for ant control in California citrus orchards: 1,2,4,5,6,7,8,8-octachloro-2,3,3a,4,7,7a-hexahydro-4,7-methanoindene (chlordane), 1,2,3,4,10,10-hexachloro-6,7-epoxy-1,4,4a,5,6,7,8,8a-octahydro-1,4,5,8-*endo-exo*-dimethanonaphthalene (dieldrin), 1,2,3,4,10,10-hexachloro-1,4,4a,5,8,8a-hexahydro-1,4,5,8-*endo-exo*-dimethanonaphthalene (aldrin), 1 (or 3a),4,5,6,7,8,8-heptachloro-3a,4,7,7a-tetrahydro-4,7-methanoindene (heptachlor), and toxaphene, a mixture of chlorinated terpenes with the average composition of $C_{10}H_{10}Cl_8$, containing 67–69 per cent chlorine.

MATERIALS AND METHODS.—Wettable-powder and emulsifiable-concentrate formulations of chlordane, dieldrin, aldrin, heptachlor, and toxaphene were used as sprays in these experiments. The formulations and amount of active ingredient used per 100 gallons of spray material are shown in tables 1 and 2. Chlordane, dieldrin, and aldrin were used also as dusts.

The materials were applied to both lemon and Valencia orange trees located in orchards in Orange and Santa Barbara counties. Plots consisted of single rows 30 trees long, replicated twice. Pretreatment counts showed that all trees used in the experiments were heavily infested with ants.

Sprays were applied with a regular hand-type citrus spray gun, using a No. 7 disc and from 300 to 400 pounds pressure. The trunk of the tree was sprayed until runoff occurred. When the branches of the trees were touching the ground, they were sprayed on both inside and outside for a distance of from 1 to 2 feet above the ground. The litter beneath the tree was also thoroughly sprayed. The amount of spray used per tree varied with the size of the tree and the density of the foliage, but experience has shown that approximately 1.5 to 3 gallons are required per tree. Spring and summer treatments have been found to be the most satisfactory; spray applications were therefore usually made either in the spring or in the summer, although two groves received a fall treatment. All dust applications were made with a rotary hand duster having an extra-long discharge tube. Dusts were applied in the fall to the trunk and lower branches of the trees and to the litter beneath. Ant infestations were recorded at monthly intervals after treatment.

WETTABLE POWDERS.—Results of spray applications of wettable-powder

[1] Paper No. 776, University of California Citrus Experiment Station, Riverside, California.

[2] Presented at the meeting of the Pacific Slope Branch of the American Association of Economic Entomologists at Santa Barbara, California, June, 1952.

[3] The author wishes to express appreciation to Julius Hyman & Company for supplying dieldrin and aldrin for use in these studies, and to the Velsicol Corporation for supplying chlordane and heptachlor. Marcus E. Cravens, deputy agricultural commissioner of Santa Barbara County, and R. J. Baumgardner, deputy commissioner of Orange County, were most helpful in obtaining experimental plots in their respective counties. John D. Paschke and Lloyd E. Vincent of the department of entomology of the University of California Citrus Experiment Station assisted in applying the sprays and making counts.

formulations of the various insecticides to Valencia orange and lemon trees are shown in table 1. Weather conditions in the fall of 1950 were such that the ants were very active, and sprays applied then remained effective for several months, as little rain fell during that time.

Spray applications of only 1 pound of the active ingredient per 100 gallons of water did not give satisfactory control of the ants on either Valencia orange or lemon trees (Table 1). Where chlordane, dieldrin, aldrin, or heptachlor was applied at the 2-pound dosage, however, Valencia orange trees were free of ants for 3 months. Over a 6-month period, heptachlor and dieldrin were more effective than chlordane or aldrin. Reinfestation of trees sprayed with chlordane or aldrin began between the third and fourth months after application.

Heptachlor spray treatments at the 2-pound dosage kept lemon trees free of ants for 7 months. Trees sprayed with dieldrin at the same dosage were free of ants for only 3 months. At the end of 7 months, the plots sprayed with chlordane, aldrin, toxaphene, and dieldrin showed 43.8, 58.6, 100, and 100 per cent infestation, respectively. Toxaphene on lemon trees reduced the infestation only 45 per cent 1 month after treatment. Toxaphene was not included in the treatments applied to Valencia orange trees.

EMULSIFIABLE CONCENTRATES.—Results of spraying with emulsifiable concentrates of chlordane, dieldrin, aldrin, heptachlor, and toxaphene at 2 pounds of active ingredient per 100 gallons of water are given in table 2. Dieldrin and heptachlor emulsion sprays kept Valencia orange trees free of ants for 8 months. Chlordane appeared to be the least effective, with 92.3 per cent of the trees showing reinfestation after 6 months.

On lemon trees dieldrin proved best, as almost 100 per cent of the trees remained free of ants for 7 months (Table 2). Chlordane was the next in effectiveness followed by aldrin. Heptachlor, however, was not so effective on lemon trees as it had been on Valencia orange trees.

Toxaphene emulsifiable spray, like the wettable-powder spray, was the least effective material tested, 96.8 per cent of the trees being infested 4 months after treatment.

DUSTS.—Results of fall applications of

Table 1.—Effectiveness of various wettable-powder formulations against the Argentine ant on Valencia orange and lemon trees.

DATE OF TREATMENT	SPRAY FORMULATION	PER CENT OF TREES INFESTED WITH ANTS[2] After Treatment (No. of Months) 1	2	3	4	5	6	7	8
	Valencia Orange Trees								
8/3/50	Chlordane, 50% (1)[1]	69.2	100	100	—[3]	—	—	—	—
	Dieldrin, 25% (1)	71.4	64.3	92.9	—	—	—	—	—
	Aldrin, 25% (1)	66.7	91.7	100	—	—	—	—	—
	Check (no treatment)	100	100	100	—	—	—	—	—
12/21/50	Chlordane, 50% (2)	0.0	—	0.0	11.1	22.2	0.0	—	16.7
	Dieldrin, 25% (2)	0.0	—	0.0	0.0	4.8	14.8	—	0.0
	Aldrin, 25% (2)	0.0	—	0.0	11.1	16.7	33.3	—	0.0
	Heptachlor, 50% (2)	0.0	—	0.0	0.0	11.1	5.6	—	0.0
	Check (no treatment)	100	—	100	100	100	100	—	100
	Lemon Trees								
8/24/50	Chlordane, 50% (1)	0.0	3.6	3.6	10.9	21.4	35.7	28.6	—
	Dieldrin, 25% (1)	0.0	0.0	20.8	42.5	62.5	87.5	79.2	—
	Aldrin, 25% (1)	8.3	12.5	16.7	25.1	12.5	33.3	45.8	—
	Toxaphene, 40% (1)	57.7	53.9	42.3	58.7	46.2	96.2	73.1	—
	Check (no treatment)	100	100	100	100	100	100	100	—
8/24/50	Chlordane, 50% (2)	3.1	3.1	18.8	26.7	25.0	50.0	43.8	—
	Dieldrin, 25% (2)	0.0	0.0	7.7	39.0	50.0	92.3	100	—
	Aldrin, 25% (2)	6.9	6.9	0.0	15.4	17.2	17.2	58.6	—
	Heptachlor, 50% (2)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	—
	Toxaphene, 40% (2)	55.6	48.1	55.6	58.0	59.3	100	100	—
	Check (no treatment)	100	100	100	100	100	100	100	—

[1] Pounds active ingredient per 100 gallons of water, given in parenthesis.
[2] All trees were infested before treatment.
[3] Dash indicates no entry.

Table 2.—Effectiveness of various emulsifiable concentrate formulations against the Argentine ant on Valencia orange and lemon trees.

Date of Treatment	Spray Formulation[1]	Per Cent of Trees Infested with Ants[2] After Treatment (No. of Months) 1	2	3	4	5	6	7	8
		Valencia Orange Trees							
12/21/50	Chlordane, 45%	6.6	—[3]	0.0	46.2	61.5	92.3	—	69.2
	Dieldrin, 25%	0.0	—	0.0	0.0	0.0	0.0	—	0.0
	Aldrin, 25%	0.0	—	0.0	22.2	22.2	27.8	—	44.8
	Heptachlor, 25%	0.0	—	0.0	0.0	0.0	0.0	—	0.0
	Check (no treatment)	100	—	100	100	100	100	—	100
		Lemon Trees							
10/13/50	Chlordane, 45%	0.0	0.0	0.0	10.0	0.0	3.3	0.0	—
	Dieldrin, 25%	0.0	0.0	0.0	0.0	4.8	0.0	0.0	—
	Aldrin, 25%	0.0	4.0	6.9	10.3	17.2	51.7	—	—
	Toxaphene, 60%	64.5	87.9	61.3	96.8	96.8	100	100	—
6/7/51	Heptachlor, 25%	0.0	0.0	35.5	45.2	12.9	25.1	—	—
	Check (no treatment)	100	100	100	100	100	100	100	—

[1] Dosage was 2 pounds of active ingredient per 100 gallons of water.
[2] All trees were infested before treatment.
[3] Dash indicates no entry.

dust concentrates of chlordane, dieldrin, and aldrin to lemon and Valencia orange trees are given in table 3.

Chlordane and dieldrin kept Valencia orange trees free of ants for 3 months. Aldrin was the least effective, keeping the trees free of ants for only 1 month. Four months after treatment 93.8 per cent of the aldrin-treated trees were reinfested.

Three months after the dusts were applied to lemon trees all trees in the plots were reinfested with ants, regardless of treatment.

DISCUSSION.—At concentrations of 1 pound of active ingredient per 100 gallons of water, spray applications of chlordane, dieldrin, aldrin, and toxaphene appeared to be slightly more effective in controlling Argentine ants on lemon trees than on Valencia orange trees. None of the materials used at the 1-pound dosage were as effective at that dosage as at the 2-pound dosage.

When the wettable-powder forms of chlordane, dieldrin, aldrin, heptachlor, and toxaphene were used in sprays at a concentration of 2 pounds per 100 gallons of water, heptachlor was found to be the most effective material on both Valencia orange and lemon trees. Dieldrin was next in effectiveness on Valencia orange trees but was less effective on lemon trees than on orange. Chlordane and aldrin were intermediate in effectiveness on both

Table 3.—Effectiveness of various dust formulations applied to Valencia orange and lemon trees against the Argentine ant.

Date of Treatment	Dust[1]	Per Cent of Trees Infested with Ants[2] After Treatment (No. of Months) 1	2	3	4	5	6	8
		Valencia Orange Trees						
12/21/50	Chlordane, 5%	0.0	—[3]	0.0	21.1	21.1	31.6	26.3
	Dieldrin, 2%	0.0	—	0.0	50.0	61.1	16.7	22.2
	Aldrin, 2%	0.0	—	18.8	93.8	100	100	100
	Check (no treatment)	100	—	100	100	100	100	100
		Lemon Trees						
11/30/50	Chlordane, 5%	—	44.5	100	100	100	100	—
	Dieldrin, 2%	—	82.4	100	100	100	100	—
	Aldrin, 2%	—	95.0	100	100	100	100	—
	Check (no treatment)	—	100	100	100	100	100	—

[1] Commercial formulations.
[2] All trees were infested before treatment.
[3] Dash indicates no entry.

Valencia orange and lemon trees, while toxaphene was the least effective of the five materials tested. This may be explained in part by the short residual action of toxaphene in comparison with the long residual action of the other materials.

At 2 pounds per 100 gallons of water, the emulsifiable forms of heptachlor and dieldrin were more effective than the wettable-powder forms. Results show that the emulsifiable form of chlordane was more effective on lemon trees than on Valencia orange trees. Toxaphene was the least effective of the emulsifiable formulations.

Results obtained with fall applications of dust concentrates of chlordane, dieldrin, and aldrin indicated that these treatments did not give practical ant control in citrus groves. In addition, it was found to be more difficult to apply dusts than sprays and obtain satisfactory coverage.

It was observed that plots of citrus trees receiving sprays for Argentine ant control became reinfested first at the borders, and that trees bordering a ravine or uncultivated area were subject to reinfestation before other trees in the plot. This indicates that the source of reinfestation generally lies outside the sprayed area.

SUMMARY.—Heptachlor, dieldrin, chlordane, and aldrin were found to be effective in controlling the Argentine ant in California citrus groves when applied as sprays to the trunks of the trees and to the lower branches where they touch the ground, as well as to the litter beneath the trees.

Sprays applied with a regular hand-type citrus spray gun at 2 pounds of active ingredient per 100 gallons of water were more effective than those applied at the 1-pound dosage. The latter were more effective on Valencia orange trees than on lemon trees. Emulsions gave more satisfactory results than suspensions of wettable powders, especially in the case of heptachlor and dieldrin.

Chlordane, dieldrin, and aldrin were less effective as dusts than as sprays, partly, perhaps, because it is more difficult to apply dusts than sprays and obtain satisfactory coverage.

Reinfestation of treated groves normally occurred first in border trees, especially in groves adjacent to ravines or uncultivated land.

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Acute Toxicity of Four Chlorinated Dimethanonaphthalene Insecticides to Chicks[1]

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In recent years there has been an increased trend towards the determination of the toxicity to poultry of insecticides which have potential use on forage crops and poultry parasites. Rosenberg & Tanaka (1950), Rosenberg & Adler (1950), Eden (1951), Arant (1952), Turner & Eden (1952), and Anderson, *et al.* (1952) are among those who have studied the toxicity of the chlorinated hydrocarbons to poultry.

This study was undertaken to compare the acute toxicity of aldrin, dieldrin, and their respective stereoisomers isodrin and endrin to New Hampshire chicks.

MATERIALS AND METHODS.—The composition of the compounds tested follows: aldrin, technical, 95 per cent with 5 per cent related compounds; dieldrin, technical, 85 per cent with 15 per cent related compounds; isodrin, recrystallized 97.5 per cent; and endrin, recrystallized, 96 per cent. Standard stock solutions of these insecticides were prepared in redistilled acetone. New Hampshire chicks of known age which were reared on standard starter and grower rations were weighed to the nearest gram. The volume of the stock solution of insecticide necessary to give a prescribed dosage to each chick was applied by means of a micropipette into a gelatin capsule. Capsule size depended upon the volume necessary to give the required dosage. The acetone was allowed to evaporate and the capsules were sealed and force-fed to the chicks. Dosage was calculated on the basis of milligrams of actual toxicant per kilogram of body weight.

After treatment, the chicks were observed for 1 week to determine symptoms of intoxication and mortality. At the end of 7 days, the surviving chicks were weighed in order to detect if there was a sub-lethal effect which might manifest itself as a sub-normal weight gain or actual weight loss.

The toxicity determinations were made primarily with 1-week-old chicks. However, in order to determine if there was any differential susceptibility that might be associated with age, the effects of these compounds on 21-day, 45-day, and 64-day-old chicks were also studied. Older chicks were treated with dosages approximating the LD-50 and LD-90 determined for the 1-week-old birds. While the 45- and 64-day-old chicks were all males, the sex of the younger age groups was unknown.

The body weight ranges for the chicks of the various ages used in this investigation were: 7-day-old chicks, 50 to 75 gms.; 22-day-old chicks, 167 to 275 gms.; 45-day-old chicks, 567 to 791 gms.; and 64-day-old chicks, 1112 to 1422 gms.

Prior and subsequent to treatment, the 7-day-old chicks were housed in electric starter batteries, the 21- and 45-day-old chicks were housed in starter batteries without heat and the 64-day-old chicks were housed in open wire floor and wire wall development pens.

EXPERIMENTAL RESULTS AND DISCUSSION.—Chicks of each of the age groups studied except 64 days were untreated and kept as controls. In addition, eighteen 7-day-old chicks were fed 0.2 ml. redistilled acetone and 19 were fed empty gelatin capsules. None of these control chicks died or showed any deleterious effects.

Toxicity of aldrin.—The toxicity of aldrin to 7-, 21-, and 45-day-old chicks is given in table 1. The LD-50 for the week-old-chicks was calculated to be 25.5 mg./kg. The older chicks were slightly more resistant to the toxic effects of this material than were the 7-day-old chicks. Death occurred within 12 hours and up to 5 days after treatment, but no relationship between time of death and either dosage or age was apparent.

Chicks affected by aldrin chirped nervously and went into convulsions. Affected birds were down on their breasts, picking nervously at the air, and thrashing forward with desperate leg movements. They

[1] Published with the approval of the Director of the Hawaii Agricultural Experiment Station as Technical Paper No. 296.
[2] Minoru Tamashiro assisted in carrying out this study.
[3] Presented at the Pacific Branch Meeting of the American Association of Economic Entomologists, Santa Barbara, California, June 1952.

Table 1.—Toxicity of technical aldrin to New Hampshire chicks of various ages. Data taken 7 days after treatment.

Dosage[1]	Number Chicks	Per Cent Mortality	Weight-Gain Ratio: Mean	Weight-Gain Ratio: Fiducial Limits P=0.05
		7 days old		
42.7	10	100	—	—
40.4	10	90	1.73	—
38.0	10	90	1.71	—
35.6	10	80	1.86	—
31.8	9	78	1.69	1.50–1.88
30.9	20	70	1.83	—
28.5	30	70	1.84	1.65–2.04
26.1	20	60	1.77	—
25.7	10	50	1.85	1.66–2.05
22.8	10	30	1.74	1.54–1.93
20.9	10	30	1.95	1.76–2.15
19.0	10	40	1.84	1.64–2.03
16.6	10	20	1.80	1.60–1.99
		21 days old		
38.0	10	10	1.37	1.28–1.46
31.8	10	30	1.40	1.31–1.49
		45-day-old ♂♂		
38.4	10	70	1.10	1.03–1.17
32.0	10	50	1.11	1.04–1.18
Untreated	11	0	1.23	1.16–1.30

[1] Milligrams of actual aldrin per kilogram of body weight.

Table 2.—Toxicity of recrystallized isodrin to New Hampshire chicks of various ages. Data taken 7 days after treatment.

Dosage[1]	Number Chicks	Per Cent Mortality	Weight-Gain Ratio: Average	Weight-Gain Ratio: Fiducial Limits P=0.05
		7 days old		
4.4	10	90	1.97	1.85–2.09
3.3	10	80	1.95	1.83–2.07
2.5	10	40	1.96	1.84–2.08
2.0	10	20	1.93	1.81–2.05
1.5	10	10	2.03	1.91–2.15
Untreated	19	0	2.04	1.92–2.16
		21 days old		
4.4	10	60	1.53	1.44–1.61
2.7	9	11	1.50	1.41–1.58
		45-day-old ♂♂		
4.4	10	70	1.09[2]	1.00–1.18
2.7	19	26	1.27[3]	1.19–1.36
		64-day-old ♂♂		
4.4	10	40	1.12	1.07–1.17
2.7	10	10	1.13	1.08–1.18

[1] Milligrams of actual isodrin per kilogram of body weight.
[2] One chick decreased 55 gms. in weight during the week of observation.
[3] Two chicks decreased in weight during the week of observation. One lost 33 gms. and the other 253 gms.

fell on their sides, fluttering their wings weakly and irregularly with their legs trembling weakly, and their heads were retracted onto their backs. After recovery from convulsions, the chicks salivated excessively.

Toxicity of isodrin.—The toxicity of isodrin to 7-, 21-, 45-, and 64-day-old chicks is presented in table 2. The LD-50 for the 7-day-old chicks was calculated to be 2.7 mg./kg. The older chicks were slightly more resistant to the toxic effects of this compound than were the 1-week-old birds. Several survivors among the 45-day-old chicks were seriously affected and lost weight during the week following treatment. These chicks apparently did little or no feeding during the 7-day observation period. Death occurred within 6 hours and up to 3 days after treatment but no relation between time of death and either dosage or age was apparent.

Symptoms of poisoning were observed in two fatally affected 1-week-old chicks. Respiration was rapid with the birds undergoing convulsions. They pushed themselves nervously forward on their keels or rolled onto their backs and wildly thrashed their legs. One of the birds lay on its side moving in circles with its head back and its wings twitching. This individual died within 5 minutes.

Post mortem examinations[4] of 1-week-old chicks killed by various dosages of isodrin revealed lesions commonly associated with a toxemia. There was general passive congestion, edema of the lungs, and degeneration of the liver and kidneys.

Toxicity of dieldrin.—The toxicity of dieldrin to 7-, 22-, and 45-day-old chicks is summarized in table 3. The LD-50 for 7-day-old chicks was calculated to be 43.0 mg./kg. The older birds were more resistant to the toxic effects of this insecticide. One 45-day-old bird which received a dosage of 53.2 mg./kg. was seriously affected; it lost 51 gms. in body weight during the week following treatment. Death occurred within 12 hours and up to 5 days after treatment but no relation between time of death and either dosage or age was apparent. Intoxicated chicks did not exhibit the nervousness associated with poisoning by aldrin or isodrin. Chicks picked spasmodically at the air while resting on their breasts.

Toxicity of endrin.—The toxicity of endrin to 7-, 21-, 45-, and 64-day-old birds

[4] These examinations were conducted by Dr. Robert F. Cross, Veterinary Pathologist, Board of Commissioners of Agriculture and Forestry, Territory of Hawaii, Honolulu.

Table 3.—Toxicity of technical dieldrin to New Hampshire chicks of various ages. Data taken 7 days after treatment.

Dosage[1]	Number Chicks	Per Cent Mortality	Weight-Gain Ratio: Average	Weight-Gain Ratio: Fiducial Limits P=0.05
		7 days old		
55.3	10	100	—	—
51.0	20	65	1.65	1.46–1.84
46.8	10	70	1.94	—
44.6	10	50	1.81	1.62–2.01
42.5	10	40	1.78	—
38.3	9	11	1.85	1.65–2.04
		22 days old		
53.1	10	10	1.35	1.26–1.44
44.2	10	10	1.35	1.26–1.44
Untreated	14	0	1.41	1.32–1.50
		45-day-old ♂♂		
53.2	10	0	1.15[2]	1.08–1.21
44.1	10	10	1.15	1.09–1.22
Untreated	11	0	1.23	1.16–1.30

[1] Milligrams of actual dieldrin per kilogram of body weight.
[2] One chick decreased 51 gms. in weight during the week of observation.

is presented in table 4. The LD-50 for 7-day-old chicks was found to be 3.5 mg./kg. The older birds were more resistant to the toxic action of this material. One survivor among the 64-day-old chicks treated with a dosage of 4.3 mg./kg. was affected so that it apparently did not feed during the week following treatment. Death occurred within 6 hours and up to 5 days after treatment. Symptoms of poisoning were similar to those caused by dieldrin. Affected chicks appeared drowsy and rested on their keels with half-closed eyes. Activity was usually below normal. Convulsions were short in duration, lasting for 20 to 30 seconds. The pathological picture exhibited by tissues in the endrin-killed chicks was similar to that caused by isodrin.

Table 4.—Toxicity of recrystallized endrin to New Hampshire chicks of various ages. Data taken 7 days after treatment.

Dosage[1]	Number Chicks	Per Cent Mortality	Weight-Gain Ratio: Average	Weight-Gain Ratio: Fiducial Limits P=0.05
		7 days old		
4.3	10	90	2.05	1.93–2.17
3.8	10	90	1.78	
3.6	10	70	1.73	
3.3	10	30	1.94	1.82–2.06
2.5	10	10	2.07	1.95–2.19
1.9	10	10	2.10	1.99–2.23
1.4	10	10	2.05	1.93–2.17
Untreated	19	0	2.04	1.92–2.16
		21 days old		
4.3	10	50	1.49	1.40–1.57
3.4	10	0	1.51	1.42–1.59
		45-day-old ♂♂		
4.3	10	40	1.16	1.07–1.25
3.4	20	0	1.19	1.08–1.26
		64-day-old ♂♂		
4.3	10	10	1.08[2]	1.04–1.13
3.4	10	0	1.13	1.08–1.18

[1] Milligrams of actual endrin per kilogram of body weight.
[2] One chick decreased 64 gms. in weight during the week of observation.

Arant (1952) determined the LD-50 of aldrin to 3- and 6-week-old New Hampshire chicks to be between 10 and 15 mg./kg. Eden (1951) determined the LD-50 of dieldrin to similar aged chicks to be between 20 and 30 mg./kg. These results are at variance with the data presented in this paper.

EFFECT OF TREATMENT ON WEIGHT GAIN.—The weight gain ratio was obtained by dividing the weight of the chick 1 week after treatment by the weight at the time of treatment. A sub-lethal effect could be expected to manifest itself in a loss of appetite, resulting in a smaller weight gain or an actual loss in body weight during the period of observation. Individual variation in appetite and utilization of food is to be expected. Such variation is greater between individuals from different broods than it is from chicks of the same brood. In order to compare statistically the effect of treatment on weight-gain it was necessary to compare chicks from the same population that were either treated with different dosage levels or with a group of untreated controls. Chicks that could be so compared were analyzed by the analysis of variance and the fiducial limits for odds of 19/1 were computed.[5] The mean weight-gain ratios of the survivors of the insecticide treatments and the fiducial limits are included in tables 1 to 4.

In general, no significant difference in weight-gain due to treatment could be determined. However, among the 45-day-old chicks receiving 2.7 mg./kg. of isodrin there was a substantially greater mean weight gain than those which received a dosage of 4.4 mg./kg., despite the fact that two individuals that received the lower dosage lost weight during the week of observation. That many of the surviv-

[5] The authors are indebted to Eugene Seu for analyzing the data.

ors were made ill by the treatments is shown by the fact that a number of the older chicks treated with dieldrin, isodrin, and endrin actually lost weight during the observation period. Others may also have been affected but overcame the toxic effects early enough to make substantial weight gains and overcome an earlier weight deficit.

CHEMICAL ABSORPTION IN TISSUES.—An experiment was conducted to determine to what degree isodrin and endrin were absorbed in chick tissues. Thirty male chicks 43 days of age were separated into three equal groups and fed isodrin at 3.4 mg./kg., endrin at 4.3 mg./kg., and one group remained untreated. One day later, livers and samples of peritoneal fat were obtained from dead chicks and survivors of the insecticide treatment as well as from the control chicks. The tissues were extracted with hexane and the insecticide content was determined by a bioassay procedure[6] which consisted essentially of exposing adult pomace flies, *Drosophila melanogaster* Meig., to the extracts as described by Sun and Sun (1952). Table 5 summarizes the results obtained. It appears that endrin is stored more readily than isodrin in both the fat and liver tissues. It also appears that the insecticide level in the animals which survived 24 hours is higher than in the animals which died within that period.

SUMMARY.—Experiments were conducted to compare the acute toxicity to New Hampshire chicks of aldrin, dieldrin, isodrin, and endrin. Gelatin capsules containing measured amounts of insecticides were force-fed to 7-, 21-, 45-, and 64-day-old chicks of known weight.

The order of toxicity of the chlorinated dimethanonaphthalenes to 1-week-old chicks follows: isodrin > endrin > aldrin > dieldrin. Isodrin and endrin were approximately 10 times more toxic than their respective sterioisomers, while aldrin was approximately twice as toxic as dieldrin. The effect of age on resistance to these materials was also similar for the stereoisomers. In general, older chicks were more resistant than 1-week-old chicks. However, this difference in resistance associated with age was greater with dieldrin and endrin than with the other two compounds.

The symptoms of poisoning produced by the stereoiosmers were similar. Aldrin and isodrin caused considerably more excitation among affected birds than did dieldrin or endrin.

Data pertaining to the weight-gain of treated chicks and the absorption of isodrin and endrin in the liver and fatty tissue are also given.

Table 5.—Residues of endrin and isodrin found in the liver and peritoneal fat of 43-day-old male New Hampshire chicks.

Tissue	Insecticidal Treatment: Compound	Insecticidal Treatment: mg./kg.	No. Chicks Sampled	Residue[1] P.P.M.
Fat	Isodrin	3.4	4 dead	<0.6
Fat	Endrin	4.3	4 alive 1 dead	6.7
Liver	Isodrin	3.4	2 alive	1.9
Liver	Isodrin	3.4	2 alive	2.0
Liver	Isodrin	3.4	2 dead	<1.5
Liver	Isodrin	3.4	2 dead	1.7
Liver	Endrin	4.3	2 alive	<3.0
Liver	Endrin	4.3	2 alive	3.1
Liver	Endrin	4.3	1 dead	<3.0

[1] Sensitivity of analysis by bioassay using *Drosophila melanogaster:*
Liver: Endrin 3.0 p.p.m.
Isodrin 1.5 p.p.m.
Fat: Endrin 3.0 p.p.m.
Isodrin 0.6 p.p.m.

[6] The bioassay determinations were made by Julius Hyman Division, Shell Chemical Corp., Denver, Colorado.

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Some Factors Influencing the Effectiveness of Parathion Against California Red Scale

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Before parathion was available, citrus growers in California depended mainly on oil sprays or the fumigant hydrocyanic acid gas for control of the California red scale, *Aonidiella aurantii* (Mask.). Studies over a period of years had established the effect of natural factors on the kill of scale by oil or hydrocyanic acid. In recent years parathion has assumed an increasingly important place in the spray program, and its use has presented many new problems. Some factors associated with the insect or the host that affect scale mortality have been noted by Carman & Ewart (1950) and Cressman *et al.* (1949). During investigations of parathion sprays between 1948 and 1952, additional data were obtained on natural factors that are important in the efficient use of parathion. They are presented here in amplification of the earlier statements made without supporting evidence, and to show the magnitude of their effects.

Materials and Methods.—Laboratory treatments were made with a pressure sprayer at a constant pressure of 35 pounds per square inch, according to the method described by Cressman (1943a). Scales of uniform age on lemons were sprayed a few days after they had begun to reproduce. Field applications were made with high-pressure sprays, both by hand and with an oscillating boom.

Mortality in the laboratory experiments was determined under a binocular microscope and in the field experiments through binocular loupes having a magnification of 3×. When external appearance left any question of mortality, it was determined from the condition of the body contents. Mortality counts in the field were made about 8 weeks after spray application and were limited to adult females.

In all experiments a 25 per cent parathion wettable powder was used. A special light oil similar to that described by Cressman *et al.* (1950) and medium oils were used. They were formulated as emulsive oils and emulsions.

Susceptibility of Scales on Different Parts of the Tree.—Red scales attack all parts of the citrus tree, but their distribution varies with the age of the fruit, the time since the last treatment, and the season. After parathion had been applied, scale mortality was recorded on different parts of the tree—fruit, gray wood or branches, green wood or younger twigs with smooth green bark, and wood that was intermediate between gray and green. Samples from any part of the tree ranged from 1,000 scales on at least 10 trees to 8,000 scales on 48 trees. Results of these experiments are shown in table 1.

Table 1.—Mortality of California red scales on different parts of citrus trees sprayed with parathion and with oil plus parathion.

Grove No.	Material per 100 Gallons of Spray		Per Cent Mortality on—			
	Parathion (25% WP) Pounds	Oil Gallons	Fruit	Gray Wood	Green Wood	Intermediate Wood
			Experiment on Valencia Orange			
1	1.5	—	61.9	99.2	91.8	—
			Experiment on Lemons			
2	1.5 and 2.0	—	48.9	86.9	59.4	—
3	2.0	—	77.3	95.7	—	—
4	1.0	1.75	—	96.0	92.6	—
5	.5	1.80	99.6	99.7	—	—
6	1.0	1.75	92.3	95.0	—	—
7	.5	1.00	—	92.5	—	90.9
8	.8	1.00	—	97.6	—	96.2

With parathion alone mortality was lowest on the fruit, highest on the gray wood, and intermediate on the green twigs. The mortality of 61.9 per cent found on Valencia oranges could be further separated into 80.2 per cent dead on mature fruit and 43.4 per cent on green fruit. Higher kills from preharvest sprays on mature oranges were observed in field inspections, but the kills on green fruit were consistently low.

Mortality counts do not give a true picture of the effectiveness of parathion on scales, since it also reduces reproduction, crawler emergence, and settling (Cressman *et al.* 1949). However, these effects are not always sufficient to prevent

considerable multiplication from surviving scales on green fruit. Other samples of green oranges from the trees furnishing the records in the first grove of table 1 were brought to the laboratory and put on water in a lath house. Forty days after they had been sprayed, all scales beyond the second instar were removed from 10 fruits. This eliminated practically all living scales that had been present at the time of treatment and probably some that had emerged shortly after the spraying. The oranges were examined again for live scales 26 days later, and on an average 126 scales were found per fruit, most of them in the second instar or later stages. Evidently many young emerged and developed after the spraying.

There was no great difference in the susceptibility of the scales to oil plus parathion that was associated with the parts of the tree on which the scales were found. The comparison of gray and green wood was based on a total count of 2,000 scales on 10 trees, and the difference was not significant. Larger samples were included in the comparisons of gray and intermediate wood. The difference was statistically significant but of little practical importance.

DENSITY OF INFESTATION.—Ebeling (1940) and Cressman (1943b) have shown that the proportion of red scales killed by oil sprays decreases as the population density increases. The relation between scale density and mortality after sprays of parathion and of oil plus parathion was examined. Population density on the fruit was estimated according to the procedure described by Cressman (1943b). Mortality resulting from parathion alone was determined from eight plots of lemons sprayed with 1, 1.5, and 2 pounds of parathion per 100 gallons. Since the density-mortality trends were very similar, mortalities for the three concentrations have been averaged in table 2. Other data were also obtained after a commercial application was made to lemons of a spray containing 1.5 per cent of oil and 0.5 pound of parathion per 100 gallons. About 22,000 scales on 128 fruits were examined from the grove sprayed with parathion alone and about 14,000 scales on 72 fruits from the grove sprayed with oil plus parathion. Results of this experiment are shown in table 2.

Table 2.—Per cent mortality of California red scale at different population densities on lemons sprayed with parathion and oil plus parathion.

Number of Adult Female Scales per Square Centimeter	Parathion	Oil (1.5%) Plus Parathion
1	37.2	96.8
3	42.9	96.8
5	45.6	96.7
7	45.0	98.1
9	42.6	93.1
11	47.4	88.7

After sprays of parathion alone, survival did not increase with the scale population. However, after sprays of oil plus parathion survival began to increase when infestation reached about 9 scales per square centimeter. Higher densities represent an extremely heavy infestation and are not often found in the field. There was no effect within the range of infestation that usually occurs.

Population density-mortality relations were also studied on gray and intermediate wood of lemons treated with a spray containing 1 per cent of oil and 0.75 pound of parathion per 100 gallons. Mortality was measured in two classes of infestation—light-to-moderate and encrusted. In the first class the lightest infestations contained about 10 scales on a 3-inch piece of twig and in the heaviest a few scales might be touching, but over 90 per cent of them were well separated from each other. Earlier unpublished studies had shown little or no effect of scale density within this range on gray wood after sprays of oil alone. In the encrusted class of infestation, at least 90 per cent of the scales were touching or overlapping. Mortality counts included 10,800 scales from 18 trees in 3 plots. The average mortality in the light-to-moderate infestation was 97.8 per cent, and in the encrusted, 95.5 per cent. The difference was statistically significant, but was not enough to be important in view of the large difference in infestation.

EFFECT OF TEMPERATURE.—Citrus trees appear to tolerate parathion equally well at all seasons of the year, although restrictions on time of application are imposed by the need to avoid poisoning bees during bloom and undue residues at harvest. The effect of temperature therefore might be important. This problem

was studied under controlled temperatures in the laboratory.

Scales reared on lemons in the laboratory at 77° F. and 70 per cent relative humidity were sprayed with parathion at the rate of 1.2 pounds per 100 gallons on July 29, 1949. Eighteen sprayed fruits were placed on a shelf in each of three constant-temperature cabinets and the same number of unsprayed fruits in space below. The shelves were about half the length of the cabinets and did not extend to either end. Each cabinet had forced-air circulation and air was taken in at a rate sufficient to change the air in the cabinet 4 times an hour. A small exhaust fan changed the air in the room about once an hour. Half the scales, about 1,000, were counted after 26 days and the remainder after 40 days, with results shown in table 3.

Table 3.—Per cent mortality of parathion-treated scales on lemons held in constant-temperature cabinets.

Temperature, °F.	After 26 Days		After 40 Days	
	Sprayed	Unsprayed	Sprayed	Unsprayed
60	74.3	2.7	95.3	6.5
75	99.2	9.6	99.9	33.5
90	100	98.5	100	99.9

The kill after 26 days was faster at 90° F. than at 60°, but at the latter temperature mortality increased greatly before the 40-day count. Mortality at 60° might have shown a further increase, if counts had been made later. In spite of the air exchange in the cabinets a marked fumigating action was shown by the mortality of unsprayed scales, and by the fact that no crawlers settled at any temperature although they emerged in large numbers on all the unsprayed lemons.

The fumigation action in the cabinets made it doubtful as to how far the results could be applied to field work, and so the problem was attacked in another way. Scales were reared as before and sprayed in the laboratory in July and January. Sprayed and unsprayed fruits were then placed on trays in different parts of a lath house, shielded from direct sunlight and rain by an overhead canvas, and held until mortality counts were made. No effect of parathion vapors or particles could be detected on crawlers on unsprayed fruits about 2 inches from sprayed lemons. The air movement was greater than exists within most citrus trees. Mortality counts were made 4 weeks after the spraying in 1950 and 4 and 8 weeks afterward in 1951. The mean temperatures during the first and second 4-week periods after the January sprays were 54.9° and 52.4° F., respectively. In the 8 weeks there were 3 days with maxima above 80° and 11 above 70°. After the July 1951 sprays the respective mean temperatures were 70.7° and 69.6°. Ten maxima were above 90° and all were above 70°. Results of this experiment are shown in table 4.

Table 4.—Mortality of scales on lemons sprayed in the laboratory and held in the lath house. Lemons sprayed ranged from 32 in the first spraying to 96 in the last.

Date Sprayed	Parathion, Pounds per 100 Gallons (25% WP)	Number of Scales	Per Cent Mortality After	
			4 Weeks	8 Weeks
July 27, 1950	0	3200	4.0	—
	0.6	1600	56.0	—
	1.2	1600	81.5	—
Jan. 8, 1951	0	3200	4.0	7.8
	0.6	3200	39.7	77.7
	1.2	3200	60.1	95.9
July 2, 1951	0	3000	5.0	—[1]
	0.6	4800	50.4	73.8
	1.2	4800	80.1	92.2

[1] Counts made impossible by development of new generations of scales.

Four weeks after the spraying, mortality was higher in July than in January, but after 8 weeks there was little difference between winter and summer results. Temperature affected the rate of kill but not the final results. The close agreement between the July 1950 and 1951 results indicates the reproducibility that can be obtained with the procedure used.

DISCUSSION.—The factor that is most important to the efficient use of parathion for control of the California red scale is the differential susceptibility of scales on fruit and wood. Because of the difficulty in killing scales on fruit, best results with parathion alone are obtained when fruit infestation is at a minimum. In general, the younger the fruit the fewer the scales. The preferred time for spraying oranges, then, is as soon as practicable after the

pick. In the case of Valencia orange, which has two crops of fruit present at the same time, it may be desirable to apply a preharvest spray in order to be ahead of green fruit infestation when the wood or mature fruit is heavily infested. Infestation on lemon fruit is usually at a minimum after the heavy winter and spring crop is picked, so that May and June are favorable months for treatment.

Oil plus parathion gave good kills on all parts of the tree. Their application is governed by the same considerations of soil moisture, and of weather and tree conditions that apply to the use of oils alone. In practice, when an annual application is made on lemons, late-summer or fall sprays have resulted in more clean fruit than spring applications, provided thorough coverage of infested fruit has been obtained. The period of heavy build-up of red scale on fruit occurs in the summer and fall and therefore spraying at that time is effective against scales on the fruit and reduces reinfestation when the most fruit is on the tree.

Density of infestation had much less direct effect on kills from oil plus parathion than from oil alone. The rather slight effect of very heavy infestation on kills from oil plus parathion appears to be one of the less important reasons why such scale populations should be prevented. In the use of parathion alone population density may have an indirect effect, since a heavy infestation on the branches is often accompanied by considerable scale on fruit and green twigs.

The experiments under controlled temperatures were inconclusive because the fumigation effect was greater than occurs in the field, and because of the possibility that further mortality might have occurred at the lowest temperature. However, the laboratory-lath house experiments indicate that, other factors being equal, temperature after spraying should have no effect on the final kill of red scales by parathion. In these experiments all scales were reared at 77° F. until the date of spraying, and the results do not eliminate the possibility that conditions during the developmental period might affect their susceptibility to parathion.

Commercial experience in 1952 gave some indication that prebloom sprays on navel oranges, applied mainly in February were less effective than postbloom treatments in May and June. More field data are needed to determine whether the scales in the field in late winter might be in a physiological condition that would make them more tolerant of parathion applied then.

SUMMARY.—Natural factors that are important in the efficient use of parathion alone and combined with oil for control of the California red scale, *Aonidiella aurantii* (Mask.), were investigated in the field and laboratory in California between 1948 and 1952. Mortality of the scales after field sprays of parathion was lowest on the fruit, highest on the gray wood, and intermediate on the green twigs. The kills by oil plus parathion were nearly equal on all parts of the tree.

Density of infestation had no effect on kill by parathion alone. With oil plus parathion there was some decrease in kill at very high levels of infestation, but little or no effect within the range of scale density usually encountered.

Differences in temperature after spraying had no effect on the final kill when scales were reared under uniform conditions up to the time of spraying in the laboratory. The rate of kill was faster at high temperatures.

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Field Experiments with Insecticides for the Control of Wireworms in Irrigated Lands

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DDT has been used extensively for the control of the sugar-beet wireworm, *Limonius californicus* Mann., in southern California during the last 6 years. Its only disadvantage is that it kills this wireworm slowly and to be effective must be applied at least 6 to 8 weeks before planting. Several other chlorinated hydrocarbon insecticides have been found to have greater initial effectiveness than DDT even when applied at low dosages. Experiments with these materials carried on in Ventura and Orange Counties, California, from 1946 to 1953, inclusive, are reported herein.

Lane *et al.* (1948) have reported some of the preliminary results with DDT in these experiments. Lane & Stone (1951) have given recommendations on the use of DDT for the control of wireworms in irrigated lands. Lanchester (1951) has reported results of laboratory tests with DDT and related materials against irrigated-land wireworms.

Procedure.—The experiments were conducted in infested lima bean fields ususally kept fallow in winter and up until the time of planting in May. Owing to the long life cycle of wireworms and the necessity for checking populations over a period of years, large plots at least 40 feet wide and 0.25 to 1 acre in size were used. Larval migration is not a problem in plots of this size. The treatments were usually made in February, March, or April, in soil that had been worked thoroughly and prepared as for the planting of lima beans. The soil in these fields varied from Yolo sandy loam to Yolo very fine sandy loam except in experiment 3 where it was Dublin clay loam. Its moisture content varied with the rainfall during the preceding fall and winter.

In the first four experiments commercial DDT or BHC dusts were applied to the soil surface by means of row-crop dusters equipped with eight nozzles spaced 15 inches apart. In the other experiments wettable-powder sprays were applied by means of power sprayers equipped with 10- or 20-foot booms, with flat-spray-pattern nozzles spaced 12 inches apart. From 80 to 100 gallons was applied per acre, depending upon the nozzle size and the speed of the equipment. The insecticides were thoroughly mixed with the soil by double disking 8 inches deep and by dragging to conserve moisture on the day the treatments were made. When the soil was too wet to disk, a spring-tooth harrow was used instead of a disk. All the fields were cultivated frequently and chiseled prior to the planting to discourage weed growth.

To determine the effect of the various insecticides, soil samples were taken at random from each plot 5 to 7 days after planting and sifted to recover the wireworms present. From 6 to 8 samples each 3 feet long, 4 inches wide, and 4 to 6 inches deep were taken from each plot. Additional information was obtained in some fields by taking from 10 to 20 samples of 0.25 square foot and 16 inches deep prior to and at intervals after the insecticide applications.

To determine the effect of the treatments on density of stand, a 0.01-acre area (4 rows 43.5 feet long) in the center of each plot was staked out before the beans emerged and the plants in this area were counted at harvest time. Yield data were obtained by picking and weighing the mature green lima bean pods or by threshing the dry lima beans from this area.

Experiments 1 and 2.—In 1946 two experiments were started on the farm of R. Borchard. In the first experiment 5, 10, and 20 pounds of DDT were used per acre. In the second experiment the 5-pound dosage was omitted and BHC at 0.5 pound of the gamma isomer substituted. The plots were 0.4-acre in size, and each treatment was replicated 4 times in randomized blocks. The insecticides were dusted on the soil surface. In experiment

[1] The experiments were made possible through the cooperation of the lima bean growers Frank, Ralph, and Robert Borchard; Henry Bruns; Joe Laubacher; Roger Edwards; and Thomas Leonard. The following field assistants obtained data on wireworm populations: R. W. Hudson, G. L. Claypool, C. O. Gaston, A. W. Sarinana, and D. H. Bixby. The Coastal Chemical Co., Oxnard, Calif., provided equipment and operators for applying the soil insecticides in experiments 4 and 5.

Table 1.—Control of sugar-beet wireworms with DDT and BHC and the effect on the stand and yield of dry lima beans. Oxnard, Calif.

Insecticide (Pounds per Acre)	Number of Wireworms Per Square Foot				Number of Wireworms Per Foot of Row					Number of Plants Per Foot of Row				100-lb. Sacks (Yield per Acre)			
	Before Treatment	Months After Treatment															
		6	10	25	1946	1947	1948	1949	1950	1946	1947	1948	1949	1946	1947	1948	1949
Experiment 1.—Insecticides applied on March 12, 1946, before irrigation																	
None[1]	3.1	3.4	1.0	1.2	3.4	0.67	1.26	0.04	—	0.8	1.4	1.5	1.8	16	27	24	26
DDT 5	2.0	1.6	0.4	0.6	2.1	.15	.07	.43	—	1.2	1.7	2.0	1.7	23	29	27	26
10	2.5	1.1	0.4	0	1.1	.02	0	.01	0.33	1.6	1.8	2.0	1.8	28	29	27	24
20	2.9	0.5	0.2	0	.5	0	0	0	.01	1.9	1.7	2.0	2.0	29	29	26	26
Difference required for significance at odds of 19:1	[2]	1.6	0.5	0.8	.8	.34	[2]	.25	—	.4	.2	[2]	[2]	7	[2]	[2]	[2]
Experiment 2.—Insecticides applied on April 23, 1946, after irrigation																	
None[1]	3.8	5.4	2.8	1.7	3.1	1.13	1.16	0.11	—	0.6	1.3	1.6	1.9	16	23	22	26
BHC (tech.), gamma ½	3.4	.3	.1	.2	.2	.06	.02	.15	—	2.0	1.8	2.0	1.8	27	24	23	26
DDT 10	3.0	2.1	.6	0	1.1	.04	.09	.09	1.21	1.4	1.8	2.0	1.8	27	25	23	26
20	2.6	1.2	.2	0	.8	0	0	.04	.05	1.8	1.8	2.0	1.8	26	22	22	26
Difference required for significance at odds of 19:1	[2]	2.4	1.1	1.7	.8	.42	[2]	[2]	—	.4	.2	[2]	[2]	8	[2]	[2]	[2]

[1] Treated with 10 pounds of DDT in fall of 1948.
[2] Not significant according to *F* test.
[3] Average number of wireworms in treated plots significantly less than in untreated plots.

1 they were applied 4 weeks before irrigation and 8 weeks before planting, and in experiment 2, 2 weeks after irrigating and 2 weeks before planting. Observations on the effectiveness of the materials were made annually through 1950.

The wireworm infestations, together with the data on stand and yields, are given in table 1.

The 5-pound dosage of DDT, although it did not give a high initial kill, greatly reduced the wireworm populations by the second year and continued to be effective into the third year. In the fourth year populations had increased to 0.4 larva per foot of row, and because of injury to the seed and plants the plots were retreated with 10 pounds of DDT per acre in October 1949. The 10-pound dosage controlled the wireworms for 4 years and gave outstanding increases in yield the first year and good yields the next 3 years (figs. 1 and 2). Owing to a decline in infestation, higher yields were obtained in the untreated plots the second year, but decreases frequently follow years of excessively high populations.

The 20-pound dosage of DDT was superior to the 10-pound dosage in being more effective initially and for the entire 5-year period. Although yields were not affected adversely, there was some destruction of seed and plants the first year in the plots receiving 10 pounds of DDT. Furthermore, this dosage had lost most of its effectiveness by the fifth year. As was indicated by the better stand and increased yields, the early application of DDT proved to be more effective than the late application.

BHC at 0.5 pound of the gamma isomer per acre was highly effective the first year and gave excellent control for 3 years. All the BHC plots were re-treated with DDT the fourth year because of a build-up in one of the plots of 0.4 larva per foot of bean row.

After tolerating 3 years of excessively high wireworm populations and low yields in the untreated plots, comprising 3.2 acres, the grower thought that some action should be taken. These plots were therefore treated with 10 pounds of DDT per acre in the fall of 1948, which accounts for the low infestations in 1949.

Experiment 3.—In the fall of 1946 dusts containing both DDT and BHC were tested in a field near Camarillo, Calif. Examination of the 1946 crop of limas showed this field to be infested with both *Limonius californicus* and *Melanotus longulus* (Lec.). BHC was used at 0.5 pound of the gamma isomer, alone and in combination with 2.5, 5, and 10 pounds of DDT per acre. Each treatment and the check were replicated 4 times in randomized blocks. The plots were 1 acre in size. These insecticides were dusted on the soil

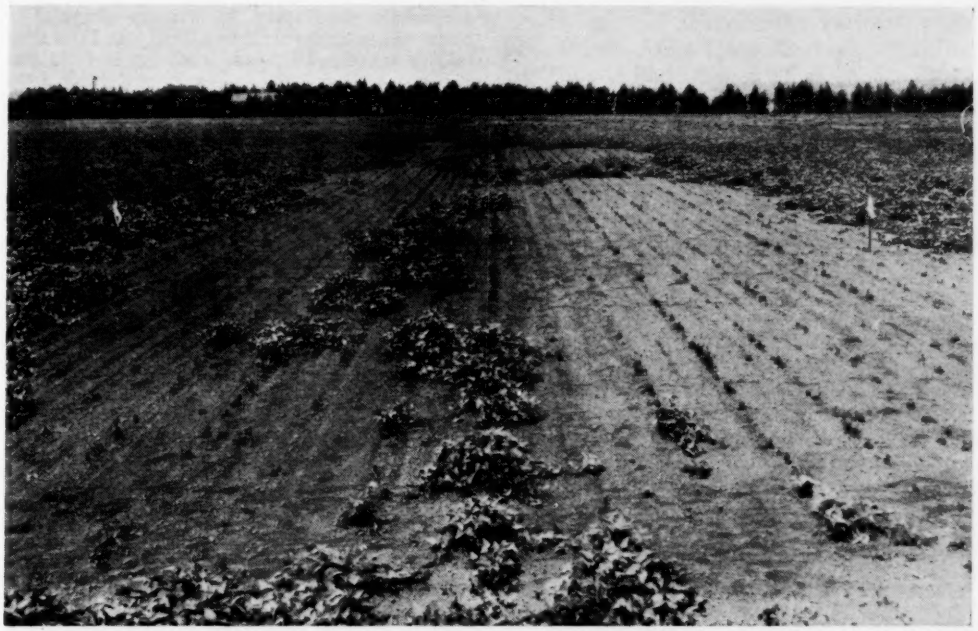

FIG. 1.—Wireworm damage to lima beans in an untreated plot in 1946.

surface on October 31, and incorporated with the soil by disking one way and plowing 12 inches deep.

The wireworm population in untreated plots showed 3 *californicus* and 0.2 *longulus* larvae per square foot in April 1947. The entire field was planted to lima beans on May 1. The insect population counts taken in bean rows for 4 years, together with data on density of stand and yields, are shown in table 2.

In 1947 all treatments were more effective against *californicus* than against *longulus*. The presence of the latter, however, did not affect yields adversely. According to the grower, the 29 sacks obtained in the treated plot represented the highest yield recorded over a 20-year period.

In 1948 all treatments were responsible for significantly lower populations of both species of wireworms, and also for significant increases in yield, with the exception of the highest dosage of DDT plus BHC. All treated plots had superior stands of beans when compared with the untreated plots, which accounts for the excellent yields of dry lima beans obtained.

To prevent further loss of beans in the check plots, the grower again thought

Table 2.—Effect of BHC and DDT-BHC dusts on populations of *Limonius californicus* and *Melanotus longulus* and on the stand and yield of dry lima beans. Experiment 3, Camarillo, Calif.

INSECTICIDE (POUNDS PER ACRE)	WIREWORMS PER FOOT OF ROW								PLANTS PER FOOT OF ROW			YIELD PER ACRE 100-LB. SACKS		
	1947		1948		1949		1950							
	californicus	*longulus*	*californicus*	*longulus*	*californicus*	*longulus*	*californicus*	*longulus*	1947	1948	1949	1947	1948	1949
None[1]	0.5	0.13	0.60	0.30	0.10	0.17	0.4	0.11	1.5	1.7	1.8	27	25	20
BHC (tech.), gamma 0.5:														
Alone	0.3	.01	.05	0	0	.03	.6	.01	1.7	2.1	2.0	29	29	21
Plus DDT 2.5	0	.03	.01	.03	0	.02	.4	.03	1.6	2.1	1.9	29	29	22
5	0	.01	.03	.04	.04	.05	.3	.04	1.7	2.1	2.1	29	29	20
10	0	.03	0	.07	0	.01	.1	.03	1.7	2.1	2.0	29	27	18
Difference required for significance at odds of 19:1	[2]	.08	.13	.16	[2]	.06	[2]	—	0.1	0.3	[2]	1.5	2.5	[2]

[1] Treated with 10 lbs. of DDT in fall of 1948.
[2] Not significant according to *F* test.

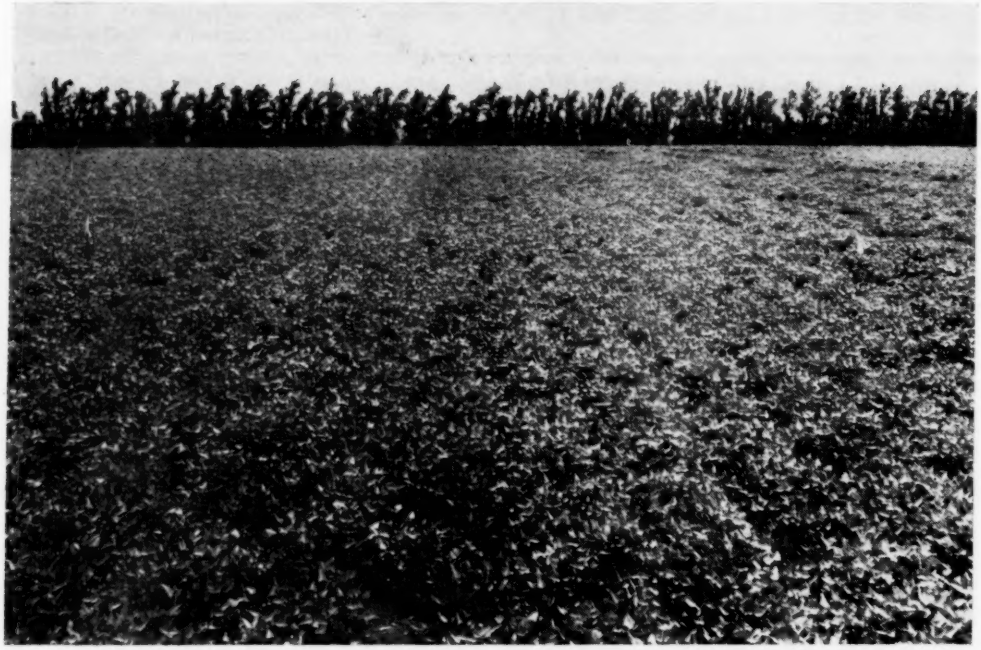

FIG. 2.—Excellent stand of lima beans in 1946 following soil treatment with 10 pounds of DDT per acre.

that some action should be taken. Therefore, after the 1948 crop was harvested, these plots were treated in the customary manner with DDT at 10 pounds per acre. As in the preceding year, a few larvae of both species survived the treatment, and there was some loss of seed and plants.

In 1949, 3 years after treating, the DDT-BHC mixture continued to give exceptionally good control of both species of wireworms. There was no significant difference between dosages in number of *californicus* larvae, number of plants, or yield of dry lima beans. However, all treatments were responsible for significant reductions in populations of *longulus*. The extremely low yields obtained in 1949 were due mainly to the below-normal rainfall and to the fact that the field had not been irrigated before planting because of an inadequate supply of water.

In 1950 data on wireworm abundance were obtained on April 11 by planting four rows of cull beans and taking six soil samples in the two center rows of each plot. Table 2 shows that populations of the sugar-beet wireworm had begun to build up in the plots treated with low dosages of DDT-BHC and with BHC alone. BHC plus the 10-pound dosage of DDT, however, appeared to give satisfactory control of *californicus* larvae into the fourth year. All dosages of this mixture gave partial control of small *longulus* larvae, since the larvae recovered were at least 2 years old.

EXPERIMENT 4.—In view of the high initial effectiveness of BHC at 0.5 pound of gamma in previous experiments, it appeared advisable to test lower dosages and to include DDT at 10 pounds per acre for comparison. The 10-acre field selected for this experiment had been planted to sweet clover in the fall of 1946. There were four 0.5-acre plots for each treatment and check. The insecticides were dusted on the cover crop on March 20, 1947, and were incorporated with the soil immediately by double-disking two ways and plowing 12 inches deep. The field was irrigated in April and the lima beans were planted on May 10. The insecticides, dosages used, together with the wireworm populations and yield data, in 1947–48 are shown in table 3.

As shown by the counts of wireworms, DDT, at 10 pounds and BHC at the 0.5-pound dosage of gamma gave excellent control of the sugar-beet wireworm for the 2-year period. The stand of bean plants was about twice that in the untreated plots. The lower dosages of BHC gave

Table 3.—Control of sugar-beet wireworms with DDT and BHC and their effect on the stand and yield of dry lima beans. Experiment 4, Oxnard, Calif.

INSECTICIDE (POUNDS PER ACRE)	WIREWORMS PER FOOT OF ROW		PLANTS PER FOOT OF ROW		YIELD PER ACRE (100-LB. SACKS)	
	1947	1948	1947	1948	1947	1948
None	3.8	1.3	0.6	1.0	12	10
BHC (tech.), gamma 0.125	1.4	1.0	.8	1.6	14	16
0.25	.6	.5	1.2	1.3	20	16
0.5	.2	.3	1.1	1.4	20	15
DDT 10	.3	.2	1.2	1.5	20	12
Difference required for significance at odds of 19:1	.75	.3	.3	[1]	4.5	[1]

[1] Not significant according to *F* test.

partial control for one season, but were not very effective the second season. For this reason and because of the reduction in yield in the check plots, in the fall of 1948 the grower re-treated the entire experimental site with DDT at 10 pounds per acre.

EXPERIMENT 5.—In 1948 seven insecticides and an untreated check were compared in each of six randomized-block replications on the farm of J. Laubacher near Oxnard. The materials were applied as suspension sprays and incorporated with the soil by spring-tooth cultivating two directions, followed by harrowing. At the time of treating, on April 9, there were 11, 13, and 14 per cents by weight of soil moisture at the 4-, 8-, and 12-inch depths, respectively. Soil temperatures at the 6-inch depth averaged 64° F. Lima beans of the Fordhook variety were planted on May 7, or 28 days after the treatments had been applied.

The wireworm population of these plots as determined on April 12 ranged from 1.3 to 2.3 larvae per square foot. This was unusually high for lima bean fields in this area. The counts of wireworms taken in the bean rows (Table 4) showed that all treatments caused significant reductions in populations in 1948. Outstanding of the materials tested were technical BHC and a commercial grade of BHC applied at 0.5 pound of the gamma isomer per acre.

Data on yields in 1948 were obtained by picking the mature green pods from 0.01 acre per plot. All insecticides were responsible for increasing the yield of this crop. In 1949–50 wireworm populations remained low in the DDT and chlordane plots, but increased in those treated with technical and gamma BHC and toxaphene. It was not possible to obtain yield data in 1949, because strong winds dislodged and mixed the samples. About the same yields of dry beans were obtained in the treated and untreated plots in 1950, in spite of the fact that populations had increased in the control plots especially.

EXPERIMENT 6.—In selecting fields for conducting wire-worm-control tests, it is always helpful to observe the damage done to the previous bean crop. In the Edwards field near Saticoy in 1948 there was about a 30-per cent loss of stand due to wireworms on 10 acres. With the own-

Table 4.—Control of sugar-beet wireworms with various insecticides and the effect on stand and yield of lima beans. Experiment 5, Oxnard, Calif.

INSECTICIDE (POUNDS PER ACRE)	WIREWORMS				PLANTS PER FOOT OF ROW			YIELD PER 0.01 ACRE IN POUNDS	
	PER SQUARE FOOT BEFORE TREATING	PER FOOT OF ROW							
		1948	1949	1950	1948	1949	1950	1948 (green)	1950 (dry)
None	1.4	1.6	0.22	0.43	1.4	1.5	1.4	70	18
Chlordane 5	1.4	.6	.07	.15	1.6	1.7	1.5	94	18
10	2.0	.5	.03	.04	1.8	1.7	1.5	101	19
Toxaphene 5	1.3	.9	.19	.15	1.6	1.6	1.5	97	19
DDT 10	1.8	.6	.03	.02	1.8	1.6	1.6	98	18
5+BHC (tech.), gamma 0.25	2.0	.4	.05	.05	1.8	1.6	1.6	100	18
BHC (tech.), gamma 0.5	2.3	.5	.07	.15	1.7	1.7	1.5	93	18
Gamma BHC 0.5	2.1	.7	.17	.36	1.8	1.7	1.5	97	17
Difference required for significance at odds of 19:1	[1]	.5	.16	.18	[1]	.1	[1]	17	[1]

[1] Not significant according to *F* test.

Table 5.—Control of wireworms with various insecticides and the effect on stand and yield of lima beans. Experiment 6, Ventura County, Calif.

Insecticide (Pounds per Acre)	Number per Feet of Row								
	Wireworms					Plants		Yield per Acre (100-Lb. Sacks)	
	californicus			*longulus*		1950	1951		
	1950		1951	1950	1951				
	April 10	May 10	May 19	May 11	May 19	July 27	August 29	1950	1951
None	0.85	1.3	1.4	0.02	0.08	1.4	1.2	23	22
DDT 10	.26	.44	.3	.01	.09	1.9	1.5	24	21
Chlordane 10	.08	.09	.2	.01	0	2.0	1.6	22	24
Toxaphene 15	.12	.37	.25	.01	.08	1.9	1.5	24	22
Aldrin 2	.24	.63	.86	.01	.03	1.8	1.4	24	24
BHC (tech.), gamma 0.5	.14	.36	.88	0	.05	1.8	1.3	25	20
Lindane 0.5	.22	.6	1.2	.02	.08	1.8	1.1	25	22
Methoxychlor 10	.78	1.0	.94	.02	.14	1.4	—	23	—
Difference required for significance at odds of 19:1	.37	.5	.46	[1]	[1]	.3	.3	[1]	[1]

[1] Not significant according to *F* test.

er's permission this area was used for testing insecticides in 1949. In this experiment there were seven insecticides and a check, each replicated 6 times in randomized blocks. The plots were 55 by 156 feet, or 0.2-acre in size. The insecticides were applied as suspension sprays on the soil surface on December 30, 1949. Owing to the very wet condition of the soil, they were incorporated with the soil by using a spring-tooth cultivator twice rather than by the customary method of disking.

From soil samples taken early in 1950 the wireworm population in the untreated plots was found to be 1.5 per square foot. Preliminary data on the effectiveness of the insecticides were obtained by planting a row of field corn through each of the six blocks on April 3 and examining them on April 10. Wireworm populations in the bean rows and data on plant counts and yields (Table 5) were obtained in the usual manner.

Higher wireworm populations were obtained in 1950 in the rows of beans 30 inches apart than in the single row of corn, which should have attracted worms from a greater distance. It was apparent that wireworms were considerably less active at the time of sampling in the row of corn. All insecticides except methoxychlor significantly reduced the wireworm populations in the corn and bean rows. Chlordane at 10 pounds per acre was especially outstanding, as the plots treated with this material were practically worm-free. All the insecticides were responsible for an increase in stand, but yields were not increased accordingly (Table 5).

Only chlordane, DDT, and toxaphene remained effective in 1951. The other insecticides failed to control the worms satfactorily. The methoxychlor-treated plots had such a poor stand that it was necessary to replant on May 28 with lindane-treated seed. An exceptionally good stand was then obtained.

It is difficult to explain the poor control of wireworms the second year with aldrin, BHC, and lindane. It is possible that the materials were not adequately incorporated with the soil. Chlordane was the only insecticide that effectively controlled larvae of *Melanotus longulus*.

Experiment 7.—On February 22, 1951, five insecticides were tested in the Leonard field near Oxnard, Calif. The entire field had been fumigated with ethylene dibromide in the spring of 1947 and then planted to lima beans every year and to lettuce in the fall of 1950. Owing to extensive damage by wireworms, only a partial crop of lettuce was harvested. Each treatment and the untreated check were replicated 6 times in randomized blocks. The insecticides were sprayed on the soil surface. To insure adequate incorporation of the insecticide with the soil, the entire field was springtoothed immediately and 4 days later double-disked

Table 6.—Control of sugar-beet wireworms with various soil insecticides and the effect on stand and yield of lima beans. Experiment 7, Oxnard, Calif.

Insecticide (Pounds per Acre)	Number per Feet of Row						Yield per Acre (100-Lb. Sacks)	
	Wireworms			Plants				
	1951	1952	1953	1951	1952	1953	1951	1952
None	1.0	0.10	0.33	1.5	1.7	1.7	30	15
DDT 10[1]	.28	.03	.08	2.0	1.9	1.9	32	14
10[2]	.24	.01	.02	2.1	2.0	2.0	35	16
Heptachlor 10	.02	0	0	2.0	1.7	2.0	33	15
Chlordane 10	.03	.01	0	2.2	1.8	1.9	35	15
Aldrin 2	.23	.06	.11	2.0	1.9	1.8	34	15
Dieldrin 2	.11	.03	.03	2.1	1.7	1.9	34	14
Difference required for significance at odds of 19:1	.39	.05	.09	0.2	.16	[3]	2.7	[3]

[1] Applied on Feb. 22, 81 days before planting.
[2] Applied on April 4, 40 days before planting.
[3] Not significant according to *F* test.

8 inches deep. The entire field was furrowed out and irrigated on March 21, and after the usual cultural operations it was planted to Fordhook lima beans on May 14, 1951. The same variety of beans was planted on May 12, 1952.

Table 6 shows that all materials gave satisfactory control of wireworms the first season. Heptachlor and chlordane, with only 0.02 and 0.03 wireworm per foot of row, were outstanding. All the treatments were responsible for excellent stands initially and until the time of harvest. All treatments except the early application of DDT were responsible for significant increases in yield over the untreated check. In the untreated plots there was some loss of seed and plants due to the presence of one wireworm per foot of bean row, and yields were reduced accordingly.

In 1951 there was no appreciable difference in the size of the population whether DDT was applied 81 or 40 days before planting. In 1952 infestations declined sharply in the untreated plots and also remained low in the treated plots. All plots except those treated with aldrin had significantly lower wireworm populations than the untreated plots. Low yields were obtained in all plots, because the beans had to be cut green at the time the remainder of the field was harvested for cold-pack purposes. In 1953 all insecticides were responsible for significantly lower populations below those in the untreated plots. Stand counts showed that differences in numbers of plants were not significant. Nevertheless, there was some reduction in plants due to wireworms in four of the untreated plots.

EXPERIMENT 8.—In 1951 an 8-acre area in the Leonard field adjacent to the plots used in experiment 7 was used to compare low dosages of heptachlor, chlordane, dieldrin, two dosages of ethylene dibromide, and a mixture containing ethylene dibromide, ethylene chlorobromide, and ethylene dichloride. There were six replicates of each treatment and check arranged in a randomized-block layout.

The insecticides were applied as suspension sprays on April 10, and they were incorporated with the soil by means of a spring-tooth harrow, and then a spike-tooth harrow was employed to smooth the surface. The fumigants were applied 8 inches deep, at 12-inch spacings, with a 10-blade commercial applicator with a spike-tooth harrow attached to seal the openings made by the injector blades. The fumigants were applied on April 17, when the soil moisture ranged from 16.3 per cent at 4 inches to 18.5 per cent between 8 and 12 inches, and the soil temperatures from 68° F. at 4 inches to 65° at 12 inches. Beans were planted on May 14. Plant counts were made in the usual manner, and yield data were obtained in 1951 only (Table 7).

Excellent control of the sugar-beet wireworm was obtained with all three insecticides when applied only 34 days before planting. Differences in number of plants or in the yields of dry beans were not significant, however, because populations were not overly high in the untreated

Table 7.—Control of sugar-beet wireworms with various insecticides applied to the soil 34 days before planting and with fumigants applied 29 days before planting in 1951 and their effect on stand and yield of lima beans. Experiment 8, Oxnard, Calif.

Treatment per Acre	Number per Feet of Row				Yield per Acre (100-Lb. Sacks)
	Wireworms		Plants		
	1951	1952	1951	1952	1951
None	0.51	0.13	1.7	1.9	35
Insecticides:					
Heptachlor 5 lb.	.02	.01	1.9	1.9	34
Chlordane 5 lb.	.16	.02	2.0	1.9	35
Dieldrin 1 lb.	.04	.07	2.0	1.9	35
Fumigants:					
Ethylene dibromide 2 gal.					
40%, 10 gal.	.04	.01	1.8	1.8	34
85%, 3 gal.	0	.01	1.5	1.9	34
Mixture of ethylene dibromide (47%), ethylene chlorobromide (47%), and ethylene dichloride (5%) 10 gal.	0	.01	2.0	2.0	34
Difference required for significance at odds of 19:1	.19	.07	[1]	[1]	[1]

[1] Not significant according to *F* test.

plots. Nevertheless, there was an increase of 0.2 to 0.3 plant per foot in the treated plots. Both strengths of ethylene dibromide were effective against wireworms, but the stand was not very good, mainly because of excessive rotting of seed. In the plots treated with 85-per cent strength 72, or 25 per cent, of 285 beans recovered in the soil samples were rotted, whereas in the untreated plots only 20, or 7.5 per cent, of the 265 beans were rotted. Since differences between the numbers of plants and between the yields of beans were not significant, the nematocidal effect of the fumigants may have been responsible for the high productivity of these plots. The fumigant mixture ethylene dibromide-ethylene chlorobromide-ethylene-dichloride was also highly effective the first year and remained effective into the second year.

Wireworm populations declined sharply in the untreated plots in 1952, and they remained low in plots treated with heptachlor, chlordane, and dieldrin. Owing to the few worms and with no differences in number of plants, evaluation of the effectiveness of these materials would be difficult.

EXPERIMENT 9.—In 1952 five insecticides were tested in six randomized blocks in a 9-acre bean field near Tustin, in Orange County. The insecticides were applied on March 6. Heavy rain (3 inches) fell in the next 2 days. Lima beans were planted on May 6.

As shown in table 8, all the insecticides were responsible for significant reductions in infestations of *Limonius californicus* and *Aeolus livens* (Lec.). Judging by the low populations in the check plots, however, neither species was present in sufficient numbers to cause appreciable damage to the bean crop.

MORTALITY OF WIREWORMS IN SOIL TREATED WITH DDT FOR CONTROL OF TOMATO FRUITWORM.—In studies for control of the tomato fruitworm, carried on by J. Wilcox in 1947, DDT was applied as a 10-per cent dust to tomato foliage at dosages of 3.8 to 17 pounds per acre.

Table 8.—Control of wireworms on lima beans with various insecticides. Experiment 9, Orange County, Calif., 1952.

Insecticide (Pounds per Acre)	Number of			
	Wireworms in 144 Feet of Row		Plants per Foot of Row	
	californicus	*livens*	May 22	August 14
None	23	13	1.3	1.0
Heptachlor 2.5	1	1	1.3	1.0
5	0	1	1.4	1.2
Dieldrin 1.75	1	0	1.3	1.2
Chlordane 5	2	0	1.3	1.1
DDT 10	4	1	1.3	1.0
Toxaphene 10	3	2	1.2	1.0
Difference required for significance at odds of 19:1	7	5	[1]	[1]

[1] Not significant according to *F* test.

Table 9.—Per cent mortality of wireworms placed in soil, in July 1948, from plots in which tomato plants had been dusted with DDT in 1947. 60 wireworms in each test. Santa Ana, Calif.

DDT PER ACRE (POUNDS)	NOVEMBER 1, 1948	DECEMBER 1, 1948
0	20	23
3.8	40	50
7.3	38	45
11.0	57	77
14.8	77	92
17.0	73	92

These plots were located in sandy loam soil on the Del Giorgio farm near Santa Ana. There were six replicates of each treatment and check arranged in randomized blocks.

Data on the toxicity of these soils to the sugar-beet wireworm were obtained by digging eight soil samples, 6 inches deep, at random near the center of each plot on July 7, 1948. The samples of soil from each plot were mixed thoroughly, moistened, and placed in 10 salve cans with one medium-sized wireworm in each can. The condition of the wireworms was determined once a month. The accumulative mortality at the time of the fourth and fifth examinations is shown in table 9.

Judging by these results, even the lowest dosages of DDT gave partial control of wireworms, and after 5 months over 90 per cent had succumbed in the soils receiving the highest dosage. It is apparent from these data that this wireworm can be kept under control by foliage applications of DDT and the plowing under of these crop residues.

SUMMARY.—Experiments were conducted in lima bean fields in California from 1946 to 1953 to determine the effectiveness of a number of chlorinated hydrocarbon insecticides against the sugar-beet wireworm, *Limonius californicus* Mann. The insecticides were applied as dusts or sprays on the soil surface and were mixed with the soil by double disking or with a spring-tooth harrow.

DDT at 10 pounds per acre, applied 6 to 8 weeks before planting, gave excellent control for 4 years, and the 20-pound dosage for 5 years.

BHC and lindane at 0.5 pound of the gamma isomer per acre were highly effective initially and controlled wireworms for 3 years.

Chlordane and heptachlor at 10 pounds per acre have given exceptionally good control of the sugar-beet wireworm for 3 years, to date, when applied 34 to 81 days before planting. At 10 pounds per acre, chlordane was also highly effective against *Melanotus longulus* Lec., a species of wireworm not adequately controlled with DDT. Heptachlor at 5 pounds per acre, applied 34 days before planting, controlled wireworms for 2 years, after which the experiment was terminated.

Dieldrin was tested at 1 and 2 pounds per acre in a field with a low initial infestation. These dosages were found to be highly effective against the sugar-beet wireworm when applied 34 to 81 days before planting, and control has already lasted for 3 years.

Aldrin at 2 pounds per acre, applied 4 months before planting, gave partial control of wireworms the first year but failed to give adequate control the second and third years. Poor control with this material may have been due to the use of a spring-tooth cultivator rather than a double-disk. Methoxychlor at 10 pounds per acre proved ineffective.

In one experiment the sugar-beet wireworm was kept under control with foliage applications of DDT for control of the tomato fruitworm and the plowing under of the crop residues.

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SCIENTIFIC NOTES

Susceptibility of Different Larval Instars of the Green June Beetle to Aldrin-Treated Soil

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A field test conducted near Holland, Virginia, in 1951 showed that 1.5 pounds of aldrin per acre applied to the soil 10 days before initial oviposition protected a Ladino clover-orchard grass pasture from injury by larvae of the green June beetle, *Cotinis nitida* (L.). A similar test in 1952 gave about the same results, not only with aldrin but also with other chlorinated insecticides. Residues apparently remained sufficient to provide nearly 100 per cent control of larvae during the entire hatching period of 3 to 4 weeks in both years. However, equal and greater dosages of aldrin failed to control second- and third-instar larvae infesting pastures later in the 1951 season, suggesting that a wide margin of susceptibility existed between the various instars.

The results of the 1951 and 1952 tests have been published (Howe & Campbell 1953a). The present paper reports the results of insectary tests conducted in 1952 primarily to determine the range of susceptibility of the three larval instars to different concentrations of aldrin in the soil. Specially prepared boxes were used as testing chambers, as described by Howe & Campbell (1953b). Aldrin dusts were incorporated in slightly moist sandy-loam soil to provide various dosages ranging from 0.25 to 4 pounds of aldrin per acre. Untreated soil was used for a check. The rearing chambers were then filled with 3 inches of soil receiving the various treatments. Treatments were randomized and replicated 4 times. The temperatures in the insectary corresponded rather closely with those occurring in the field. Twenty first-instar larvae and 15 each of second- and third-instar larvae were introduced into each chamber in each test. The larvae had been reared according to the method described by Howe & Campbell (1953b). First-instar larvae were introduced 24 to 48 hours after hatching, and second- and third-instar larvae a few days after moulting.

At 5-day intervals the soil was removed from each rearing chamber, and all larvae were sorted out and counted. The soil was then returned to its original chamber. Dead larvae were discarded and those showing movement were placed on the surface of the replaced soil. Larvae incapable of burrowing into the loosened soil were considered to be moribund; those able to burrow back into the soil were counted as living.

The results of the tests are summarized in table 1. All first-instar larvae were killed within 5 days with the 0.25-pound dosage of aldrin. Second- and third-instar larvae were progressively more resistant to the insecticide. Aldrin at 2 pounds per acre killed all second-instar larvae in 5 days or prevented them from burrowing back into the soil. A 100-per cent kill of third-instar larvae was obtained only after exposure to the 4-pound dosage for 20 days, but the 2-pound dosage killed or prevented 91 per cent from burrowing in 10 days and 96 per cent in 20 days.

Based on comparative LD-50 values obtained from dosage-mortality curves, first instars were approximately 10 times as susceptible to aldrin as third instars and 5 times as susceptible as second instars. At the smallest dosage burrowing and food consumption by first-instar larvae were sharply reduced after 24 hours' exposure. Some second instars were killed during ecdysis, 7 to 10 days after introduction, indicating a greater susceptibility at that time.

Little further moribundity or mortality occurred among the few surviving second- and third-instar larvae after 20 days' exposure to 0.25 and 0.5 pound of aldrin per acre. Loss of toxicant and increased age of the larvae may have accounted for their continued survival.

The dosages applied in these tests were not necessarily those required for field control, where weathering and leaching by rains would be influencing factors. However, the high susceptibility of first-instar larvae to low dosages of aldrin in these tests explained the excellent control observed when field applications were made before the eggs hatched.

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Table 1.—Susceptibility of the three larval instars of the green June beetle to aldrin in the soil. Holland, Va., 1952.

Pounds of Aldrin per Acre	Per Cent of Larvae Moribund or Dead After Indicated Exposure								
	5 Days			10 Days		15 Days		20 Days	
	First	Second	Third	Second	Third	Second	Third	Second	Third
0	0	0	0	0	0	0	0	0	0
0.25	100	9	7	60	7	89	7	96	11
0.5	100	31	9	86	18	93	24	98	24
1	100	71	32	97	48	98	75	100	78
2	100	100	67	100	91	100	93	100	96
3	100	100	81	100	95	100	95	100	96
4	100	100	88	100	98	100	98	100	100

Evaluation of Acaricides on Orchard Mites in 1952[1]

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Acaricidal evaluation tests were conducted in several apple orchards in 1952. For European red mite, *Metatetranychus ulmi* (Koch), these were divided into an early season experiment and one carried out in July when the population was at or near its maximum level for the season. Experiments on two-spotted spider mite, *Tetranychus bimaculatus* (Harvey), were conducted in August.

EUROPEAN RED MITE, EARLY TESTS.—Studies conducted in 1951 showed that materials like TEPP applied during the late pre-blossom or "pink" bud stage were more effective than calyx applications and equal to or better than 2 per cent petroleum oil spray put on in the delayed dormant stage. In 1950, however, the calyx application of TEPP was just as efficient as the pink spray, Lienk & Chapman (1951). This difference in the performance of TEPP for the two seasons is attributed to the fact that mite and tree development are not closely synchronized. To obtain more information on this point, similar tests were run in 1952. The results with TEPP for the three seasons are summarized in table 1. Also shown here are the number of days elapsing between first hatch of the overwintering eggs and the time that the calyx sprays were applied. The developmental rate of females including the pre-oviposition period during the early season is approximately 15 to 16 days. In 1950 only 16 days elapsed between the beginning of egg hatching and the end of bloom when the calyx sprays were applied. Consequently, only a few eggs for the first summer generation were deposited by this time, and the control obtained with pre- and post-bloom sprays was similar. In 1951 and 1952, the period between the first egg hatch and calyx was extended. Under these conditions a high percentage of new eggs was already present when the calyx stage was reached. Possibilities of this character limit the effectiveness of materials like TEPP which possess short residual and little or no ovicidal action. Generally the pre-blossom (pink) sprays gave better results than calyx applications in all three years for most acaricides tested.

Table 1.—Efficiency of TEPP (8 oz. 20% liquid) applied as pre- or post-bloom sprays for European red mite control. 1950–1952.

Season	Days Between First Hatching and Calyx Spray	Hatched Mites per Leaf[1]			
		Pink	Calyx	Pink and Calyx	Untreated
1950	16	2	7	1	236
1951	20	30	67	3	167
1952	26	3	10	2	53

[1] Mite population records taken at the time of peak activity in each year.

The results of all tests made during the early season period are shown in table 2. Demeton used at the 4-ounce level again gave just as good control when applied at the pink as during the calyx period. At the dosage tested, the delayed dormant application proved slightly inferior.

EUROPEAN RED MITE, SUMMER TESTS.—Fourteen materials and various formulations of these were evaluated as single sprays against a summer European red mite infestation. The experimental procedure and technique were the same as described by Chapman & Lienk (1950) in a previous paper.

[1] Journal Paper No. 928, New York State Agricultural Experiment Station, Geneva, N. Y., May 25, 1953.

Table 2.—Efficiency of several acaricides against the winter eggs and newly hatched larvae of the European red mite on Baldwin apple. Alloway, N. Y., 1952.

Material and Formulation	Rate per 100 Gals.	Date(s) Sprayed[1]	Hatched Mites per 10 Leaves			
			7/7	7/21	7/28	8/11
Petroleum oil[2]	2 gals.	4/22	5	15	89	2
Demeton (32% liq.)[3]	4 ozs.	4/22	12	62	136	2
Demeton (32% liq.)	4 ozs.	5/5	2	10	42	27
Demeton (32% liq.)	4 ozs.	5/26	3	8	40	21
Demeton (32% liq.)	4 ozs.	5/5, 5/26	0	6	13	7
TEPP (20% liq.)	8 ozs.	5/5	2	2	27	13
TEPP (20% liq.)	8 ozs.	5/26	7	24	100	7
TEPP (20% liq.)	8 ozs.	5/5, 5/26	1	4	22	28
Geigy 338 (25% emul.)[4]	16 ozs.	5/5	8	18	38	30
Geigy 338 (25% emul.)	16 ozs.	5/26	11	13	108	8
Geigy 338 (25% emul.)	16 ozs.	5/5, 5/26	2	13	43	42
Parathion (15% w.p.)	1 lb.	5/5	4	9	53	5
Parathion (15% w.p.)	1 lb.	5/26	12	6	35	7
Parathion (15% w.p.)	1 lb.	5/5, 5/26	2	9	31	43
Parathion (15% w.p.)	2 lbs.	5/26	6	13	87	6
Parathion (15% w.p.)	2 lbs.	6/6	4	10	53	4
Parathion (15% w.p.)	2 lbs.	5/26, 6/6	1	10	56	50
Ovotran (50% w.p.)	1 lb.	5/26	3	31	167	7
Controls:			143	527	148	4

[1] Bud stages on treatment dates were: 4/22 delayed dormant; 5/5 pink; 5/26 calyx; 6/6 10-day spray.
[2] A "superior" type dormant tree spray oil. For specifications see Jour. Econ. Ent. 42: 45. 1949.
[3] 0,0-diethyl 0-2-(ethylmercapto)-ethyl thiophosphate. Systox. Chemagro Corporation.
[4] 2-hydroxy-2,2-bis(4-chlorophenyl) ethyl acetate. Geigy chlorobenzilate. Geigy Company, Inc.

Table 3.—Efficiency of several acaricides against the European red mite on Northern Spy apple, Phelps, N. Y., 1952.

Plot No.	Material and Formulation	Rate per 100 Gals.	Per Cent Reduction in Population		
			Days After July 4 Sprays		
			3	10	17
1	Demeton (42% liq.)[1]	2 ozs.	98.5	100	100
2	Demeton (42% liq.)	4 ozs.	99.1	100	99.9
3	Geigy 337 (25% emul.)[2]	1 pt.	98.5	87.5	83.7
4	Geigy 338 (25% emul.)[3]	1 pt.	99.0	95.8	95.6
5	Geigy 367 (25% emul.)[4]	1 tp.	95.6	94.6	89.5
6	Geigy 358 (25% emul.)[5]	1 pt.	96.2	99.8	99.8
7	Geigy 359 (25% emul.)[6]	1 pt.	95.3	98.8	98.6
8	Malathon (25% w.p.)	2 lbs.	97.2	99.6	98.6
9	Malathon (50% emul.)	1 pt.	96.5	98.7	96.9
10	Parathion (15% w.p.)	1 lb.	98.7	99.8	99.5
11	NPD (25% w.p.)[7]	2 lbs.	99.3	98.5	97.3
12	Tag (10% liq.)[8]	0.5 pt.	91.7	71.5	—[10]
13	Crag (34% liq.)[9]+3 lbs. lime	2 pts.	96.6	67.9	—[10]
14	Sulphenone (50% w.p.)	3 lbs.	94.4	94.9	94.6
15	Aramite (15% w.p.)	1.5 lbs.	98.1	98.5	97.1
			Average No. Hatched Mites per Leaf		
Controls:			239	104	59

[1] 0,0-diethyl 0-2-(ethylmercapto)-ethyl thiophosphate. Systox. Chemagro Corporation.
[2] Ethoxymethyl-di-(p-chlorophenyl) carbinol. Geigy Company, Inc.
[3] 2-hydroxy-2,2-bis(4-chlorophenyl) ethyl acetate. Geigy chlorobenzilate. Geigy Company, Inc.
[4] 0,0-diethyl-0-(2 isopropyl-4-methyl-pyrimidyl (6)) thiophosphate. Geigy Company, Inc.
[5] 0,0-diethyl-0-5 (3 methylpyrazolyl) thiophosphate. Geigy Company, Inc.
[6] Diethyl-5-(3 methylparazolyl) phosphate. Geigy Company, Inc.
[7] Tetra-n-propyl dithionopyrophosphate. E. I. du Pont de Nemours & Company, Inc.
[8] Phenyl mercuric acetate. California Spray Chemical Company.
[9] 2 heptadecyl glyoxalidine acetate. Carbide & Carbon Chemical Corporation.
[10] Not counted. Appeared to equal population in controls.

The materials tested and data obtained are given in table 3. Attention is called to the high mite population present initially in this orchard. Although the population was apparently at its peak when treatments were applied, July 4, it remained at a sufficiently high level for a critical evaluation of the materials tested. It is interesting to note that the systemic pesticide, demeton, even at the two-ounce level gave perfect control.

Observations earlier in the season indicated that the fruit tree fungicides[2] may have some acaricidal value. Therefore, these materials were included in the present test. Both materials, as shown by the three-day count, gave good immediate control; however, they are weak in residual action for mite populations in these plots appeared to have reached the same level of the controls, 17 days after treatment.

Aramite gave only fair control of the European red mite in our 1949, 1950 and 1951 evaluation tests. Against the two-spotted spider mite it has always given excellent results. As shown in table 3, Aramite gave excellent results against European red mite in 1952. A possible factor affecting the results obtained with this material last season was the high temperature that prevailed at treatment time and for some days thereafter.

Two-Spotted Mite Test.—To conserve space no specific data will be presented on the acaricidal evaluation experiment conducted on the 2-spotted spider mite in 1952. For, the control with most products tested was almost uniformly high—96 to 99+ per cent control efficiency 10 days after the initial treatments were applied. Single applications made August 11 gave essentially as good results over the observational period of 31 days as did dual treatments applied August 11 and 21. Materials tested and concentrations used in these tests were the same as shown from plots nos. 1, 2, 4, 5, 6, 7, 8, 9, 10, 11, 14 and 15 in table 3. Important additions were: parathion, used at a 2-pound rate, Aramite combined with hydrated lime (3 lbs.) and DDD used at 2 lbs. of the 50 per cent wettable powder.

In the present experiment, the killing efficiency of Aramite was high and unaffected by the presence of hydrated lime. Counts in DDD treated trees showed control of 28.4, 53.8, 86.0 and 71 per cent in records taken 2, 10, 22, and 31 days, respectively, after a single spraying. It went to 92 and 90 per cent in the 22- and 31-day count, respectively, following the application of a second spray. Mite population in control trees averaged 45, 71, 89 and 54 hatched forms per leaf 2, 10, 22 and 31 days, respectively, after the initial test sprays were applied August 11.

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[2] "Tag" and "Crag."

Preliminary Tests with DDT Paint

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Block (1948) reported that in recent years many paints containing DDT have been used for the control of insects. Numerous workers investigated the possibilities of incorporating DDT in different types of paints, washes and coatings, and have reported varying degrees of success. Its use in granaries may be limited or completely prohibited due to possible contamination of food. However, there are possibilities of using a paint containing DDT by coating ceilings and outside walls of houses, granaries, and warehouses.

MATERIALS AND METHODS.—The paint containing DDT used in the present investigation was sold under the trade name "Smart Brite Blue." It is an oil type paint that contained 2.5 per cent DDT and 97.5 per cent inert materials. The interior of ice cream cartons, 4.5 cms. deep and 8.0 cms. in diameter, were painted with Smart Brite Blue. These treated surfaces were exposed to adult rice weevils, *Sitophilus oryzae* (L.) and adult confused flour beetles, *Tribolium confusum* Duval, at varying periods. Beetles used in these experiments were obtained from cultures that in no case were more than 6 weeks old. In all cases untreated cartons were used for checks. One hundred insects were used in each carton for each exposure. The length of exposure for every test was 48 hours, however, observations were made with shorter exposure periods. At the end of this period the dead insects were counted and the live insects placed in clean culture bottles containing food. These were examined every day and the number of dead insects was recorded until all the insects, other than those alive in the checks, were dead. The experiment was conducted at room conditions where the temperature varied from 20° to 24° C., and the relative humidity from 45 to 60 per cent. During the experiment observations were made on the relative susceptibility of male and female rice weevils when they were exposed to the toxic surfaces. Experiments were replicated thrice. When the adults came in contact with the treated surface they fell on their backs, kicked their legs back and forth, and stopped feeding.

RESULTS AND CONCLUSIONS.—The results (Table 1) show that when rice weevils were exposed to the treated surface immediately after it had dried for 48 hours 100 per cent mortality occurred in 3 days. This period increased up to 9 days when the age of the treated surface was 14 weeks. Similar effect was shown upon the confused flour beetle, however, the time necessary to obtain 100 per cent mortality was greater at any given age of the treated surface, *i.e.*, the confused flour beetle was more resistant to DDT than the rice weevil. It should be noted that as the age of the treated surface increased, the time necessary to obtain 100 per cent mortality also increased. Exposure period less than 48 hours did not have appreciable effect on the beetles, excepting immediately after the treatment of the carton and 1 week following the treatment. Toxic surfaces immediately and 1 week after treatment were almost equally effective against the confused flour beetle.

The differential susceptibility of female and male rice weevil to the treated surface is clearly indicated in table 2. Males died even during the exposure period whereas females were not affected until 2 days after exposure. When adults were exposed for 48 hours to the DDT-containing paint, 100 per cent mortality occurred in 7 days in the case of males and 9 days in the case of females. This indicates that males die sooner than females when exposed to the treated surface. This difference in behaviour of male and female adults is important in considering the formulations and efficiency of the insecticides.

Table 2.—Mortality of male and female rice weevils when exposed for 48 hours to a surface treated with a paint containing 2.5 per cent DDT.

SEX	PER CENT MORTALITY, ON DAYS INDICATED, FOLLOWING EXPOSURE PERIOD									
	0[1]	1	2	3	4	5	6	7	8	9
Male	4	8	28	64	76	84	88	100		
Female	—	—	12	44	52	60	64	80	84	100

[1] Died during exposure period.

Table 1.—Mortality of adult beetles when exposed for 48 hours at varying intervals to a surface treated with a paint containing 2.5 per cent DDT.

AGE OF DDT-PAINTED SURFACE IN WEEKS	TREATMENT	PER CENT MORTALITY,[1] ON DAYS INDICATED, FOLLOWING THE EXPOSURE PERIOD									
		0[2]	1	2	3	4	5	6	7	8	9
		Rice weevil									
0	DDT	52	68	98	100						
1	DDT	24	60	80	94	100					
3	DDT	16	56	86	94	98	100				
6	DDT	6	54	86	90	96	98	100			
14	DDT	2	4	20	54	64	72	76	90	92	100
		Confused flour beetle									
0	DDT	8	19	30	71	99	100				
1	DDT	36	64	84	92	96	100				
3	DDT	20	36	68	84	84	92	100			
6	DDT	12	20	48	76	80	84	84	100		
10	DDT	4	12	32	56	72	76	84	92	92	100

[1] There was no mortality among equal numbers of these beetles exposed to untreated surfaces.
[2] Died during exposure period.

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Horse Fly and Horn Fly Repellent Tests on Cattle in New York

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This report is a continuation of the research reported by Goodwin, Sloan and Schwardt (1952). They concluded that a 1 to 10 dilution of pyrenone (1% pyrethrins+10% piperonyl butoxide) applied at the rate of 1 quart per animal afforded the best protection against horse flies and horn flies of the material tested. The study was resumed in order to evaluate two recently developed materials as well as to veryify the previous results.

The most numerous species of horse flies occurring in the vicinity of Ithaca, N. Y. during the summer of 1952 were *Tabanus lasiopthalmus* Macquart, *T. quinquevittatus* Weidman, and *T. sulcifrons* Macquart. This is in agreement with the findings of Tashiro and Schwardt (1949). Other species which were collected and determined throughout the season included: *T. superjumantarius* Whitney, *T. lineola* Fab. var. *scutellaris* Walker, *T. atratus* Fab., *T. pumilus* Macquart, and *T. trispilus* Weidman. The check herds showed a higher population of horse flies in 1952 than in either the 1950 or 1951 seasons. The horn fly, *Siphona irritans* (L.), was also quite abundant during the 1952 season.

MATERIALS AND METHODS.—The following repellents were tested: pyrenone,[1] butoxypolypropylene glycol,[2] sulfoxide pyrexcel,[3] and Experimental Compound 370.[4] All of these materials were emulsifiable concentrates. The repellents were applied with a small portable power sprayer to the entire body surface of the cattle. Approximately 1 quart was used on each animal. Applications were made between 6:00 A.M. and 8:00 A.M. before the cattle were turned out to graze.

The treatments were timed to coincide with the peak populations of the three important species. The first application was applied on July 2, which was about 1 week after *Tabanus lasiopthlamus* Macquart reached its peak. The second and third applications were timed for *T. quinquevittateus* Weidman, which occurs from early July until late August. The second application was made on July 17. The third application was also employed against *T. sulcifrons* Macquart being made on August 12. Population estimates of horse flies were determined by counting the number of flies on 10 cattle. An examination of one side of the body of 10 cattle was used to obtain the density of the horn fly population. Observations were made between 1:00 P.M. and 5:00 P.M. of the day of treatment and on the third, fifth, and seventh days thereafter. Two check herds located in the near vicinity of the treated herds were utilized as controls. An average of the check herd counts was computed for comparative purposes.

DISCUSSION AND RESULTS.—The pyrenone treatments gave a consistently high degree of repellency of horse flies (Table 1). Butoxypolypropylene glycol appeared slightly less effective. Sulfoxide pyrexcel exhibited poor results in the first treatment while excellent results were obtained in the second treatment. Therefore further work with this repellent is needed. Experimental Compound 370 exhibited poor repellency of horse flies, however only a single herd was sprayed with this material.

[1] U. S. Industrial Chemicals Inc.
[2] Carbide and Carbon Chemical Corp.
[3] S. B. Penick and Company.
[4] Geigy Company, Inc.

Table 1.—Tests with horse fly repellents applied on July 2, July 17 and August 12, 1952. Ithaca, New York.

Materials and Concentrations	Days After Treatment				Total Flies	Per Cent Reduction
	1	3	5	7		
	Number of Flies					
Pyrenone 1-10	0	0	1	1	2	97
Pyrenone 1–10	0	1	3	1	5	94
Butoxypolypropylene glycol 1–9	1	8	8	0	17	79
Butoxypylpropylene glycol 1–9	0	6	5	3	14	83
Check	20	8	50	2	80	—
Pyrenone 1–10	0	0	0	0	0	100
Butoxypolypropylene glycol 1–9	0	1	0	4	5	87
Butoxypolypropylene glycol 1–9	3	3	20	10	36	05
Sulfoxide pyrexcel 1–9	2	3	14	9	28	26
Experimental Compound 370[1]	5	3	6	9	23	39
Check	10	6	5	17	38	—
Pyrenone 1–10	0	3	2	—[2]	5	85
Butoxypolypropylene glycol 1–5	0	10	9	—	19	42
Butoxypolypropylene glycol 1–9	0	3	2	—	5	85
Sulfoxide pyrexcel 1–9	0	3	0	—	3	91
Check	8	16	9		33	—

[1] Applied at the rate of 13 ounces per gallon of water.
[2] Heavy rain on 6th day.

Table 2.—Tests with horn fly repellents applied on July 2, July 17 and August 12. Ithaca, New York.

Materials and Concentrations	Days After Treatment				Total Flies	Per Cent Reduction
	1	3	5	7		
	Number of Flies					
Pyrenone 1–10	0	5	0	0	5	99
Pyrenone 1–10	0	5	0	0	5	99
Butoxypolypropylene glycol 1–9	0	5	20	0	20	98
Butoxypolypropylene glycol 1–9	0	0	0	100	100	94
Check	525	110	350	700	1685	—
Pyrenone 1–10	0	0	0	25	25	99
Butoxypolypropylene glycol 1–9	0	0	0	100	100	98
Butoxypolypropylene glycol 1–9	0	5	20	0	25	99
Sulfoxide pyrexcel 1–9	0	0	0	250	250	95
Experimental Compound 370[1]	10	90	1000	2000	3100	40
Check	1000	1300	1350	1550	5200	—
Pyrenone 1–10	0	0	0	—[2]	0	100
Butoxypolypropylene glycol 1–5	0	0	0	—	0	100
Butoxypolypropylene glycol 1–9	0	0	0	—	0	100
Sulfoxide pyrexcel 1–9	0	0	150	—	150	97
Check	1800	1750	1850	—	5400	—

[1] Applied at the rate of 13 ounces per gallon of water.
[2] Heavy rain on 6th day.

Horn flies were effectively repelled with both pyrenone and butoxypolypropylene glycol for as long as 5 to 7 days (Table 2). A lower repellent value was evident with the sulfoxide pyrexcel and Experimental Compound 370.

CONCLUSIONS.—Emulsifiable pyrenone (1–10 dilution) was the most effective combination horse fly and horn fly repellent tested. A single spray treatment applied immediately after the early morning milking repelled the flies for a period of from 5 to 7 days depending on weather conditions.

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Life History of *Blaberus giganteus* (L.)

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Blaberus giganteus (L.) is one of the largest cockroaches, it and certain of its congeners perhaps being surpassed in size only by some South American species of *Megaloblatta*. Some specimens of *giganteus* measure as much as 55 mm. in over-all length. This cockroach is found in Central and South America (Rehn and Hebard 1927), where it is known by several common names, such as the giant cockroach, the giant drummer, and the cockroach of the devine face —the last name no doubt being due to the picturesque markings on the pronotum. Hebard (1917) states that a similar species, *Blaberus craniifera* Burm., occurs in Florida, perhaps the result of an early introduction. There is little information available on the life history of either of these insects. It is the purpose of this paper to record the life-history observations obtained during the successful rearing of *giganteus* at Beltsville, Maryland, over a three-year period. These insects were reared at 85° F. and 60 per cent relative humidity by the method of Piquett and Fales (1952).

Blaberus giganteus has been described as an ovoviviparous species. According to Hagan (1951), the term "ovoviviparous" applies to that type of viviparity in which an egg with a chorion develops in the maternal oviduct into an embryo, which hatches before deposition. The capsule is membranous rather than a hard scleritized pouch such as that of most domestic cockroaches. There is no information in the literature to indicate that either *giganteus* or *craniifer* ever deposits egg capsules under normal conditions.

Blaberus giganteus has a long life span. One specimen in the laboratory has lived 612 days as an adult and is still alive at this writing. Another individual died after 532 days as an adult. Three of the first nymphs obtained were isolated in order to obtain information on the number of times they molt before becoming adults. Two of them molted seven times, the remaining one eight. Two of the nymphs required 180 days to become adults and the other 167 days. Their sex was not determined.

In another experiment the female of a pair of adults reared from nymphs that were born on February 8, 1951, gave birth to nine young on January 13, 1952, making the birth-to-birth cycle 11 months and 5 days or 330 days. These nine nymphs (five females and four males) were placed in separate cylindrical glass cages for rearing. It took an average of 167 days for the males to become adults and 174 days for the fe-

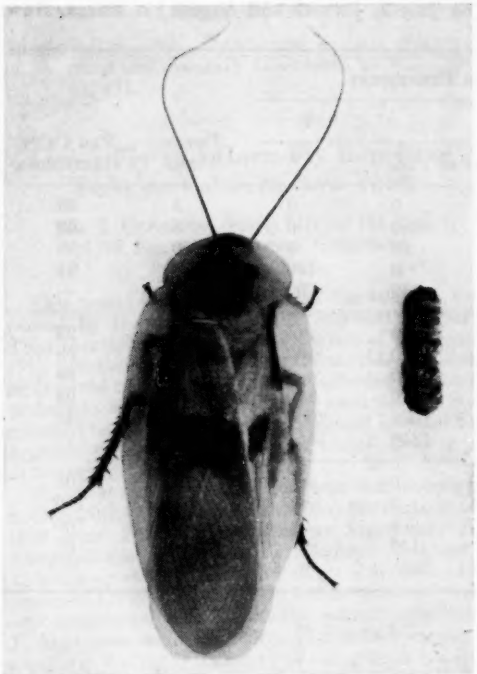

FIG. 1.—Adult female and a premature egg capsule of *Blaberus giganteus* (¾ actual size).

males, duplicating closely the results of the first experiment, but in which the individuals were not separated by sex.

On April 1, 1952, nine nymphs were produced by another female. The single survivor became an adult in 184 days after molting seven times.

On the basis of 13 reared individuals of both sexes, *giganteus* averaged 172 days after hatching to become adult, the minimum time being 139 and the maximum 201 days. Records of molting on four individuals reared during these studies disclose that either seven or eight nymphal stages occurred. It is barely possible, of course, that additional moltings occurred and that the exuviae were eaten, but there was no indication of such an occurrence.

Figure 1 shows an adult *Blaberus giganteus* and an egg capsule 22 mm. long that extruded and dropped when a female of this species was treated with an insecticide. Nutting (1953) in reporting on the reproduction of *B. craniifera* Brum. noted this ovoviviparous species may also discard oötheca.

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Transmission of the Western X-Disease Virus from Sweet and Sour Cherry to Peach by Two Species of Leafhoppers[1, 2]

H. R. WOLFE[3] and E. W. ANTHON[4]

Insect transmission of the western X-disease virus from diseased peach to healthy peach has been demonstrated in Oregon, Washington and Utah with the leafhopper, *Colladonus geminatus* (Van D.) (Wolfe *et al.* 1951). In Washington, experimental transmission of the virus from diseased peach to healthy peach has also been obtained with the leafhoppers, *Fieberiella florii* (Stål), *Scaphytopius acutus* (Say) and *Keonolla confluens* (Uhl) (Anthon & Wolfe 1951). The western X-disease virus, as it occurs in Utah, has also been transmitted from diseased chokecherry to healthy peach by *C. geminatus* (Kaloostian 1951).

The first insect transmission of the virus from diseased sweet and sour cherry to healthy peach was demonstrated in Utah by Kaloostian (1951) with *Colladonus geminatus*. First transmission of the virus, as it occurs in Washington, from diseased sweet cherry to healthy peach was obtained by Anthon & Wolfe (1951) with the leafhopper, *Fieberiella florii*. The purpose of this paper is to report experiments conducted at the State College of Washington, Tree Fruit Experiment Station, Wenatchee, demonstrating first transmission of the virus, as it occurs in Washington, from both sweet and sour cherry to peach by the leafhoppers, *C. geminatus* and *Scaphytopius acutus*.

Test insects for the experiments were secured by rearing them upon suitable hosts in cages in the greenhouse and from field collections. The western X little cherry affected trees used as a source of virus were naturally infected cherry trees in commercial orchards. Most of the test trees were Lovell peach seedlings grown in 6-inch pots in the greenhouse. They were from 3 to 6 inches tall when first exposed to the test insects. Six test trees were three-year-old Elberta peach trees in the field. The feeding time of the test insects on the source of virus varied from 8 to 65 days—on the test trees, 4 to 79 days.

In an experiment involving transfers of *Colladonus geminatus* to a total of 21 trees, four positive transmissions were obtained from infected sweet cherry to healthy peach (Table 1). Two of the four transmissions were from the Lambert variety and two were from Napoleon (Royal Ann). One of these transmissions was from Napoleon to a three-year-old Elberta peach tree in the field. The other three transmissions were to Lovell peach seedlings growing in the greenhouse.

[1] Scientific Paper No. 1225, Washington Agricultural Experiment Stations, Pullman. Project No. 848.

[2] This work represents cooperative efforts of the following agencies: the Washington State Department of Agriculture, the Washington Agricultural Experiment Stations, and the United States Department of Agriculture.

[3] Supported by the Washington State Department of Agriculture.

[4] Supported in part by the United States Department of Agriculture, Bureau of Entomology and Plant Quarantine.

Table 1.—Transmissions of the western X-disease virus to peach by *Colladonus geminatus* which had fed on western X little cherry affected sweet cherry as a source of virus. Wenatchee, Washington, 1951.

Variety of Inoculum	No. of Insects per Test	No. of Tests	Transmissions
Lambert	1	5	2
Napoleon	1	10	1
Napoleon	50	3	1
Napoleon	100	3	0
Totals		21	4

Five transmissions were obtained in tests with *Scaphytopius acutus* which fed on diseased sweet cherry as a source of virus (Table 2). One was from Lambert and four were from Napoleon. All test trees were Lovell peach seedlings in the greenhouse.

In transfers of *Colladonus geminatus* from diseased Montmorency sour cherry to healthy Lovell peach seedlings in the greenhouse, five transmissions were achieved (Table 3). In two of these cases the insects acquired the virus while in the nymphal stage.

Table 2.—Transmissions of the western X-disease virus to peach by *Scaphytopius acutus* which had fed on western X little cherry affected sweet cherry as a source of virus. Wenatchee, Washington, 1951.

Variety of Inoculum	No. of Insects per Test	No. of Tests	Transmissions
Lambert	1	4	1
Napoleon	1	6	4
Totals		10	5

In an experiment involving serial transfers of 15 *Scaphytopius acutus* to a total of 47 trees, 12 transmissions were obtained from infected Montmorency to Lovell peach seedlings in the greenhouse. The leafhoppers were left on the source of virus for 35 days. After feeding on the inoculum, adult leafhoppers were placed singly on 3-inch potted Lovell peach seedling test trees. In this experiment in which 15 insects were used, 15 test trees were involved in the first "set" of tests. The leafhoppers were left on the peach trees for 10 days and then moved to another set of test plants. This serial transfer, involving movement of insects to new test trees every 10 days, was continued for as long as the test insects survived.

Table 3.—Transmissions of the western X-disease virus to peach by *Colladonus geminatus* which had fed on western X little cherry affected sour cherry as a source of virus. Wenatchee, Washington, 1951.

Variety of Inoculum	No. of Insects per Test	No. of Tests	Transmissions
Montmorency	1	10	2
Montmorency	2	2	1
Montmorency	12	1	1
Montmorency	25	2	1
Totals		15	5

Eight of the 15 leafhoppers became viruliferous (Table 4). Four effected transmission before being transferred from the first test trees in the series, indicating that the latent period of the virus in these insects was not more than 45 days. In three cases the maximum latent period may have been 65 days. This was based upon the interval between the first day the insects were placed on the source of virus and the last day they were exposed to the test trees. However, if these insects had acquired the virus during the last few days they were on the source of virus, the latent period would have been correspondingly less. After becoming viruliferous and transmitting the virus to test trees, three leafhoppers apparently failed to transmit the virus when they were transferred to additional test trees in the series. One vector transmitted the virus to three trees in succession when moved at 10-day intervals.

Table 4.—Transmissions of the western X-disease virus to peach by single adult *Scaphytopius acutus* which had fed 35 days on western X little cherry affected Montmorency sour cherry as a source of virus. Insects were transferred serially at 10-day intervals. Wenatchee, Washington, 1952.

Insect	Test Tree Sequence				
	1	2	3	4	5
1	−[a]	−	−[b]		
2	+	+	+		
3	−	−	+		
4	−	−	−		
5	−	+	−	−	
6	−	−	−		
7	−	−	+		
8	+	−			
9	−	−	−		
10	+	+			
11	−				
12	+	0	+		
13	−	−	−	−	−
14	−	−	−	−	
15	−	−	+	−	−

[a] The minus sign (−) indicates no virus transmission, and the plus sign (+) indicates production of the disease. 0 indicates test tree died before expiration of time usually required for symptom expression.

[b] The discontinuance of each series of transfers was due to the death of the insect.

In the above experiments single adults of both species of leafhoppers transmitted the virus. First symptoms of the disease appeared in most of the test trees in the greenhouse approximately 60 days after exposure to infective leafhoppers. Six of the test trees growing in the greenhouse, however, did not show symptoms until 60 days after they had undergone a dormancy period of 90 days at 35° F. The Elberta peach test tree in the field which became diseased did not show symptoms until approximately 1 year following inoculation by the insects. Peach trees, both in the greenhouse and in the field

held as controls, have remained free of the disease. Graft transmissions from the infected test trees to Lovell peach seedlings in the greenhouse resulted in western X-disease symptoms within 60 days, proving the presence of a transmissible virus.

SUMMARY.—The western X-disease virus, as it occurs in Washington, has been transmitted experimentally from diseased sweet and sour cherry trees to healthy peach by the leafhoppers, *Colladonus geminatus* (Van D.) and *Scaphytopius acutus* (Say). Transmissions of the virus have been secured by single adult insects of both species of leafhoppers. All transmissions but one were to small Lovell peach seedling trees growing in the greenhouse. One transmission by *C. geminatus* was from diseased sweet cherry to a three-year-old Elberta peach in the field. In two transmissions from sour cherry to peach by *C. geminatus*, the insects acquired the virus as nymphs. Both insect vectors transmitted the virus to peach from Lambert and Napoleon (Royal Ann) varieties of sweet cherry, and from Montmorency sour cherry to peach. In transmissions from sour cherry to peach, the minimum latent period of the virus in *S. acutus* was not more than 45 days, and the maximum may have been as much as 65 days, depending upon when the insect acquired the virus.

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A Comparison of the Toxicity of Mamey Seed Extract and Rotenone

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The reports found in the literature on the insecticidal properties of mamey (*Mammea americana* L.) contain conflicting opinions concerning the possibilities of using mamey as a source of a commercial insecticide. De Grosourdy (1864) first reported the use of mamey as an insecticide. Tattersfield *et al.* (1926), after carrying out extensive insect-feeding tests, did not consider mamey to be sufficiently toxic to warrant further investigation. Plank (1944) and Sievers (1949) found mamey to be toxic to many species of insects, and highly toxic to phytophagous insects. They concluded that mamey could be used as a convenient source of insecticidal material. More accurate evaluations could have been made if quantitative data had been available for comparison with corresponding data on some well-known and widely used insecticide. Such quantitative data are presented in this paper.

Mamey extracts were prepared by soaking the powdered seed in chloroform for 48 hours, a procedure which extracted about 5 per cent of the weight of the dry seed, including all toxic materials. The chloroform of a suitable aliquot was evaporated and the residue weighed and dissolved in alcohol. The rotenone standards were also dissolved in alcohol. The guppy method (Pagán, 1949) was used in toxicity tests of both mamey and rotenone.

Preliminary trials were conducted in order to determine the approximate toxic threshold, During these trials, visual observation of the poisoned fish suggested a mode of action different from that of rotenone. In contrast to the effect of rotenone, which is thought to be one of suffocation through the destruction of the gill epithelium (Danneel 1933), the toxic action of mamey extract on guppies caused a frantic dashing about, and later, spasmodic twitchings. Respiratory movements were irregular and forced; and the higher concentrations exerted a strong paralytic action as shown by rigid outstanding fins. Since the effect of mamey extract on guppies is similar to that of phenols on goldfish as described by Gersdorff (1939), it is of interest to note that recent work done at this station has shown the toxic components of mamey to be weak phenolic acids (Morris, 1952).

Three tests were made on as many different extractions of mamey seed. The toxicity threshold of these extracts was found to be 1.3 p.p.m., as compared to 0.02 p.p.m. for rotenone. The median lethal dosage for the extracts was 1.7 p.p.m., representing 30 mg. of the seed, whereas only 0.05 p.p.m. of rotenone, equivalent to 0.5 mg. derris root, was needed to kill 50 per cent of the fish population. Rotenone is therefore about 30 times as toxic as mamey extract to the guppy, and derris root is about 60 times as toxic as mamey seed.

The striking differences between the toxic action of mamey extract and rotenone were also noticed on the dosage-mortality curves. The slope of the curve for mamey was steeper, showing that once the toxic threshold was reached a relatively small addition of poison produced complete kill. Whether this is due to the comparatively large differences in toxicity or to the particular type of action, especially as regards complexity of physiological action, remains to be determined.

The active ingredients in the crude extract were separated and isolated by columnar chromatography. Briefly, a petroleum ether solution of mamey extract was placed on a column of silicic acid and developed by washing with ether and petroleum ether mixtures. Two toxic and four non-toxic zones were formed on the column. From the lower toxic zone two crystalline compounds were recovered. The medium lethal dose to guppies for these compounds was 1.5 p.p.m. From the second toxic zone a golden-yellow, amorphous solid was obtained with a median lethal dose to guppies of 0.25 p.p.m. The chemical characteristics of these three compounds, which account for over 90 per cent of the toxicity of mamey, are reported elsewhere (Morris and Pagán, 1953).

Since the above data show that mamey-seed powder is only 1.7 per cent as toxic as derris-root powder, and in view of the difficulties that would be encountered in the cultivation of mamey, it is highly unlikely that it will ever attain the status of a commercial insecticide.

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An Acaricidal Formulation for Canine Demodecosis

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The dog follicle mite, *Demodex canis* Leydig, has been a very difficult parasite to control because it is so imbedded in the hair follicles and sebaceous glands. In the past many treatments such as alcohol, chaulmoogra oil, cresol, garlic, iodine, rotenone, sulfur, tar, and X-ray have been recommended for demodectic mange. These were slow, generally ineffective, and usually disappointing. Since 1944 an increasing number of papers have been written recommending various acaricidal preparations for demodecosis containing benzyl benzoate or chlorinated insecticides (Davidson 1945, Dodson 1947, Estrada 1948, and Muma & Spencer 1948). Because of the effectiveness of benzyl benzoate or organic insecticides such as DDT or BHC used singly, it was decided that some combination of these chemicals would be even more efficient. Various mixtures of benzyl benzoate and DDT compounded with other chemicals to increase the penetration and adherence were tried and the following formula was found to be the most effective:

Benzyl benzoate	20 ml.
DDT	1 gm.
Stearic acid	2 gm.
Tween 80[1]	12 ml.
Water	66 ml.

The benzyl benzoate and stearic acid are warmed together until the stearic acid dissolves. Then the rest of the ingredients are added. Benzyl alcohol or benzocaine may be added to ease any possible pruritus. To insure adequate penetration the emulsion was applied liberally and thoroughly massaged into the skin. The size of the area treated depended upon the severity of the infestation. However, in infestations of even moderate intensity one half of the body surface was treated every third day, including areas that showed no mange symptoms. This was done as the mite spreads and builds up tremendous populations before damage to the hair follicle brings about the typical mange symptoms. This treatment was continued until the surface had been treated three times. As the effects of the medication were not immediately observable externally, skin scrapings were taken 3 to 5 days after the initial application and these showed a very high mortality. If no live mites or new symptoms were noted after 30 days following the final treatment, no further treatment was needed. In no case were any untoward effects observed.

This mite is apparently an opportunist and parasitizes only dogs weakened physically and with low resistance. It is therefore important to build up the physical condition of the infested animals by a vitamin-enriched, high protein diet, deworming if necessary, and better general care.

It was noted that the usual proprietary mixtures and simpler formulas did not have sufficient antiseptic or healing properties to remove the secondary infections usually accompanying chronic demodectic mange. The above formula aided in clearing up these secondary invaders and allowed the infected areas to heal, due perhaps to the benzyl benzoate.

[1] *Tween 80*. Polyoxyethylene (20) sorbitan monocoleate manufactured by Atlas Powder Co.

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Notes on Certain Ectoparasites in Massachusetts

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Recently some specimens of fleas were brought in for identification that were reported as occurring in the nest boxes and probably other regions of a chicken house. According to our information, the fleas hopped on the men collecting eggs and bit them. The fleas were identified tentatively as *Orchopeas*, probably *howardii*, which was listed as an ectoparasite occurring on grey squirrels.

In order to have a positive identification and also to determine whether or not this flea had been regarded as a poultry pest, we sent the specimens to Dr. G. P. Holland, Dept. of Entomology, Ottawa, Canada, who identified the fleas as *Orchopeas howardii* Baker. He stated, "I have never heard of this

species attacking chickens, and I believe there are only one or two records of its biting man." In his excellent monograph of the fleas of Canada, Holland (1949) discusses the distribution and hosts of this flea. He states that apparently *Orchopeas howardii* is a true parasite of the grey squirrel, *Sciurus carolinensis*, and is limited in its distribution by the presence of the host. He does indicate that occasionally this flea does occur on other hosts.

In 1951, Coher & Shaw presented some data that appeared to indicate that the American dog tick, *Dermacentor variabilis*, had extended its range. Two adult male ticks were collected under circumstances which seemed to exclude the possibility of the specimens having been brought into the region during the same season.

In 1953 an engorged female of *Dermacentor variabilis* was removed from a dog in Amherst, Mass. There is no record of the dog having been in other areas of the state where the dog tick occurs endemically. Hence, this record seems to substantiate the earlier belief that *Dermacentor variabilis* is increasing its distributional range.

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White-Fringed Beetle Surveys in Noninfested States

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White-fringed beetles, *Graphognathus*, spp., are now known to occur in small portions of eight southeastern States—namely, Alabama, Florida, Georgia, Louisiana, Mississippi, North Carolina, South Carolina, and Tennessee. These insects are native to Argentina, Brazil, Chile, and Uruguay, where they are considered as major pests only in local areas. The insects are believed to have been introduced into the United States through several ports on the Gulf Coast and through the port at Wilmington, North Carolina. Inasmuch as the insect does not fly, its natural rate of spread is rather slow.

On the basis of data collected in South America, the potential range of the beetles in the United States extends from the latitude of Philadelphia, Pennsylvania, (57° F. isotherm) on the north to the lower end of the Florida peninsula (70° F. isotherm) on the south. The mean annual temperature and the latitude range presumably are not the only factors influencing their distribution. The temperature of the soil in winter, soil type, and land usage probably are also important. Therefore surveys for white-fringed beetles in noninfested areas in the United States should not be restricted to the potential range.

The wingless parthenogenetic adult beetles begin emerging from the soil during May, reach peak abundance during July and August, and most of them die off in the early fall. The eggs are deposited in masses of about 11 to 14, and usually are attached to some object at the point of contact with the soil. This habit is important because it relates to the dissemination of these pests. During the summer eggs hatch in about 17 days, and the small, legless larvae dig their way into the soil.

The larva, which is the normal overwintering stage of the insect, is usually found in the upper 9 inches of soil. Owing to the wide range in dates of egg hatching and rate of larval growth, larvae of various sizes can be found in the soil in any month of the year. Pupation usually begins in late April and reaches a peak in early July. The pupation period averages 13 days. Normally there is only one generation a year; however, a small percentage of the larvae remain in the soil for two or three years.

The principal damage by white-fringed beetles is caused by the larvae feeding on the roots and underground stems of young plants. The larvae are general feeders and have been observed feeding on 240 species of plants, including many major field and garden crops as well as ornamental herbaceous plants. Generally they cause more damage to plants with a tap-root system than to those with a fibrous-root system, such as small grains.

When larval feeding is severe, the plants become yellow, wilt, and die. Larval surveys in cropland areas can be conducted by watching for the characteristic injury to the plant, and where such injury is noted examining the soil for the larvae. The larvae also feed upon the roots of native weeds and at times cause a noticeable loss of vigor; therefore, surveys in noncropland areas for the larval stage of the insect are also effective. Where injury to the plant is noted, soil samples are dug and examined by hand for the presence of the larvae. As the adult beetle spends the greater portion of its life on the ground, where it deposits eggs beneath vegetative growth, such as goldenrod, broomsedge, dog fennel, and wild aster, the soil around such areas provides good locations for examination for the presence of larvae. Although larval surveys are utilized in portions of those States where infestations are known to exist, they are not recommended generally for use in noninfested States, except as they may be accomplished incidental to other work and in special cases where crop damage similar to that caused by white-fringed beetles may be noted.

The most rapid and effective survey in noninfested States is accomplished by inspecting for the adult beetles. Although the adults do not normally cause severe economic damage, they feed on a wide variety of native broadleaf weeds as well as crop plants. In general they prefer the legumes, and rarely feed on members of the grass family. The beetle makes a characteristic feeding design on the leaves, which is used as a guide in inspections. When the plant is approached, the beetle has the habit of falling from the plant and simulating death. In inspections for the adult beetle examinations are made for this characteristic feeding design, and if the feeding were done by the white-fringed beetle the adult will usually be found under or near the plant.

White-fringed beetles have two primary means of distribution from known infestations in the Southeast, one in connection with the shipment of nursery stock and the other along principal highways and railroads in connection with the movement of agricultural products and industrial supplies. In planning inspections in noninfested States, consideration is given to the probable avenues of spread from the

[1] The author has drawn freely from information presented in Circular No. 850 of the U. S. Department of Agriculture, entitled "White-fringed Beetles and How to Combat Them," by H. C. Young, B. A. App, J. B. Gill, and H. S. Hollingsworth.

southeastern United States and to possible importations directly from South America. Important places for inclusion in surveys are (a) ports of entry, with particular attention to areas where materials are received from South America; (b) principal railroad and truck transportation centers and distribution points, with primary consideration to those serving the Southeast; (c) points where scrap metal is received, particularly from locations in the Southeast; (d) military installations, with special consideration to areas where supplies are unloaded, troop-receiving areas, and refuse-disposal areas; (e) nurseries, with particular attention to those importing stock; (f) properties to which nursery stock was shipped from locations in the Southeast prior to the discovery of infestations; (g) farm crop-processing or storage areas and stockyards. Inspections of these places will indicate the possibility of infestations in farming sections.

The close cooperation of the Bureau of Entomology and Plant Quarantine and State pest-control agencies has resulted in an adequate inspection program. Personnel of the two organizations should continue to work together in planning a well-organized comprehensive survey program. Since special inspection techniques are necessary for the detection of white-fringed beetles, State officials should be encouraged to send employees to infested areas for adequate training. When this is not possible, a Bureau representative might meet with State employees in their State to discuss inspection techniques and give field demonstrations.

Infestations are more likely to be found in their incipient stage if trained State employees make observations for white-fringed beetles in connection with their normal work assignment with assistance from experienced Bureau employees as time permits. State employees are continually visiting all sections of their State, whereas Bureau surveys must be restricted to the areas covered during periodic inspection tours. State employees trained in white-fringed beetle inspection techniques can make an adequate inspection of nurseries in connection with their annual State nursery inspections. Assistance on special surveys by trained Bureau employees therefore should be restricted for the most part to other areas within the State. As it is impossible to cover all States or all portions of a single state during any one season, the plans should provide for a progressive inspection program with priority being given to those areas where infestations are most likely to have been introduced.

During the last several years personnel of the Bureau of Entomology and Plant Quarantine have conducted surveys in the District of Columbia and assisted State employees in scouting 13 States—namely, Arkansas, Delaware, Illinois, Indiana, Kentucky, Maryland, Missouri, New Jersey, Ohio, Pennsylvania, Texas, Virginia, and West Virginia. In 1946 and 1947, following the discovery of infestations in nurseries in Georgia, special inspections by Bureau employees of nursery-stock planting sites and nurseries were conducted in portions of these States and 10 additional States—namely, California, Connecticut, Iowa, Kansas, Massachusetts, Michigan, Minnesota, Nebraska, New York, and Oklahoma. Pest-control officials of a number of States have arranged for their inspectors to be on the look-out for white-fringed beetles in connection with their other inspection activities, and many of the officials have arranged for experienced Bureau employees to train their personnel in white-fringed beetle inspection techniques. Much of this training has been accomplished in known infested areas.

In conclusion the following recommendations are stressed:

1. That provision be made for the training of state employees in white-fringed beetle inspection techniques.

2. That Bureau and State officials work closely together in organizing a progressive inspection program in each State.

3. That the States arrange for observations to be made for white-fringed beetles in connection with routine inspection activities, and that the Bureau arrange to assist in such surveys as determined by the hazards of introductions both from South America and from known infested areas in the southeastern United States.

Effect of Wear and Aging on Residues of DDT Used to Prevent Insect Damage to Woolen Rugs

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The use of DDT for protecting woolens against insect damage has been advocated since 1944 (Anon. 1944). This insecticide has been used extensively on woolen rugs. Since it has been shown that wool normally has no affinity for DDT (Moncrieff 1950), the insecticide is subject to removal by wear and vacuum-cleaning. Tests were therefore conducted to determine (1) the rate of insecticide loss due to wear, vacuum-cleaning, and aging, and (2) the duration of effectiveness of the treatment under such usage.

PROCEDURE.—An all-wool, looped, twisted-pile rug weighing 4.1 pounds per square yard and measuring 18 by 72 inches was treated with a 5 per cent (w/v) solution of DDT in deodorized kerosene at the rate of 0.5 per cent by weight of the rug. This rate was obtained by using 186 ml. of the DDT solution (9.307 grams of DDT) per square yard. It was applied to the upper surface of the rug with a 3-gallon compressed-air hand sprayer at 20 pounds pressure.[2]

One day after treatment the rug was placed in a room in such a manner that half of it was exposed to heavy walking traffic. This section was vacuum-cleaned once each week. The other half was located under a desk, and therefore received only occasional use and no vacuum-cleaning. Light, temperature, and humidity during the 18-month test period were the same for both sections of the rug.

Periodically 1 by 2 inch samples were removed from both sections of the rug for conducting biological tests, and pieces 4 inches square were removed for chemical determinations of DDT. The biological tests were conducted in accordance with the CSMA excrement-weight method (Anon. 1952), which consisted in exposing the rug sample to 10 black carpet beetle larvae in open petri dishes for 28 days.

[1] The authors are indebted to L. L. McDonald and C. Cueto for assistance in conducting some phases of the biological tests and chemical analyses.

[2] A Tee-Jet No. 8002 fan type, No. 33, was used.

Table 1.—Results of tests conducted with a rug sprayed with 5 per cent DDT oil solution. Rate of application was 0.5 per cent of DDT by weight of the rug, but analysis showed actual deposit to be 0.49 per cent. Average of four replications.

Age of Treatment (Months)	Wear to Which Rug Was Exposed	DDT Concentration by Weight of Rug (Per Cent)	Excrement Weight (Mg.)	Weight of Cut Fibers (Mg.)	Visual Damage
1	Light	—	2.3	2.2	None
	Heavy	—	5.8	3.8	Very light
	None[1]	—	15.6	2.7	Moderate
6	Light	—	0.7	0.8	None
	Heavy	—	2.4	1.7	Very light
	None[1]	—	14.6	4.2	Moderate
9	Light	0.41	1.9	0.1	None
	Heavy	0.17	3.4	0.2	Very light
	None[1]	0	16.4	5.3	Heavy
12	Light	0.49	3.2	0.3	None
	Heavy	0.18	6.2	1.0	Light
	None[1]	0	25.8	15.9	Very heavy
18	Light	0.40	1.8	0.7	None
	Heavy	0.07	7.8	0.7	Light
	None[1]	0	33.3	16.9	Very heavy

[1] Untreated.

The tests were conducted in a room having a constant temperature of 80°±2° F. and a relative humidity of 60±5 per cent. At the end of the exposure period the insect mortality, excrement weight, cut-fiber weight, and visual damage were recorded. The AOAC method for total benzene-soluble chlorine (AOAC Methods 1950) was used for determining the amount of DDT on the rug.

Results.—The results of these tests are given in Table 1. At the end of 18 months the original DDT deposit on the rug of 0.49 per cent was reduced to 0.40 per cent by light wear and to 0.07 per cent by heavy walking traffic and weekly vacuum-cleaning. No insect mortality was obtained in the biological tests, but the treatment prevented damage by black carpet beetle larvae for the entire 18 months on the rug section exposed to light wear, and very light to light damage was obtained on the section subjected to heavy walking traffic and weekly vacuum-cleaning. The excrement and cut-fiber weights showed that the DDT treatment was still rendering a high degree of protection even on the rug exposed to heavy walking traffic and weekly vacuum-cleaning.

Since insect damage to rugs usually occurs along the periphery of the rug and to sections that are seldom exposed to wear such as under furniture, the results of these tests indicate that DDT applied at the rate of 0.5 per cent by weight of the material will protect woolen rugs against insect damage for a minimum of 18 months under most conditions.

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Injury to Cattleyas by an Eriophyid mite[1]

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Careful observation of the new growth of Cattleyas in a greenhouse of the Department of Entomology, University of Maryland, revealed small brown areas just above the line of the sheath and a dark brown or almost black sheath. These areas became darker and more heavily cutinized as the leaf unfolded. The frequency of these lesions led to a careful microscopic examination of the injured plants that revealed the presence of an eriophyid mite. These were sent to H. H. Keifer, Sacramento, California, in 1949. He determined that they belonged to the genus *Aceria*. Beginning in 1952 W. C. Atcheson, a graduate student, was assigned to the study of the biology of this mite and the details reported herein are taken very largely from his Master of Science thesis.

Orchids frequently show brown or black injured areas particularly in the early stages of development and these injuries enlarge with the development of the leaf and persist through the life span of that particular leaf. Most growers disregard such develop-

[1] Technical description of this mite by Atcheson and Keifer will appear in the Bulletin of the California Department of Agriculture.

ments and blame the condition on faulty watering, ventilation or temperature control. Actually many lesions are caused by some organism, a mite, scale, thrip or a disease and it is essential that these causes be segregated from the usual environmental factors. With full knowledge of just how the injury from any pest manifests itself, the investigator may speak with assurance in regard to these baffling spots, sunken areas and blackened sheaths.

The female mite is yellowish white about 180–200 microns in length, spindle-shaped, and has the curious habit of rearing up on the tip of its abdomen. The male is slightly smaller. The mites congregate beneath the sheath on young pseudobulbs and feed there apparently taking advantage of the contact afforded by the sheath. When numerous they may "swarm" or collect at the tip of a leaf or the developing pseudobulb. This could be a method of dispersal. The entire life history is completed in an average of 23.5 days. The incubation period of 56 eggs averaged 5.6 days. The larval stage averaged 4.9 days. The feeding and active period of the protonymphs average 5.5 days. The deutonymphs averaged 7.5 days. Adults lived an average of 20 days.

Control was affected by a spray of Triton X100. Twenty cc. of Triton X100 dispersed in 80 cc. of water was used as a stock and 20 cc. of the above mixture was used in 1 quart of water as the spray. Lime sulphur 3 tablespoonfuls to 1 quart of water gave over 50 per cent control. Red Arrow Garden Spray,[2] *Dimite*[3] and *Kilmite*[4] were ineffective at the dilutions used.

[2] McCormick & Co., Baltimore, Md.
[3] Miller Chemical Co., Baltimore, Md.
[4] Acme Quality Paints, Inc., Detroit, Mich.

Soil Treatment Tests for Control of the Pale Western Cutworm[1]

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In the spring of 1951, a moderate infestation of the pale western cutworm, *Agrotis orthogonia* Morr., in several non-irrigated wheat fields near Loveland, Colorado, presented an opportunity to test a number of insecticides for the control of this species. The pale western cutworm is subterranean in its habits and is not readily controlled by poison baits and surface sprays as are most of the common cutworms that feed above ground.

On April 27 and 28, two acre plots were sprayed with a low pressure (40 lbs.) weed sprayer. After spraying, one-third of each plot was harrowed with a spike toothed harrow, one-third was treated with a tine weeder, and one-third was left undisturbed. A week after treatment each plot was examined by digging through the top soil with a garden fork until 50 or more worms were found. The insecticides (emulsifiable, except where applied with fertilizer applicator), rates used, and per cent mortality are shown in table 1.

Practically all of the dead worms were found on the surface of the soil. The TDE, dieldrin, and aldrin, gave sufficiently high mortality to be considered practical controls.

The grower, on whose farm the tests were conducted, used aldrin to treat parts of several fields and was satisfied with the control obtained. In one field, treated with 8 oz. aldrin per acre, 0.38 inch rain fell before the harrowing operation had been carried out. The control obtained in this field appeared to be as good as that in fields where harrowing followed the insecticide application.

Table 1.—Insecticide tests on pale western cutworm, Loveland, Colorado, 1951.

Materials and Rates Used per Acre	Per Cent Mortality		
	Tine Weeder	Harrowed	Undisturbed
Toxaphene, 3 lbs./25 gals.	35.0	48.5	19.0
Toxaphene, 2 lbs./13 gals.	42.5	36.0	21.4
TDE (DDD), 1.5 lbs./13 gals.	96.1	100.0	91.6
TDE, 1 lb./7 gals.	66.6	89.3	75.7
Dieldrin, 8 oz./13 gals.	100.0	97.4	97.1
Dieldrin, 8 oz./7 gals.	98.3	100.0	55.0
Aldrin, 8 oz./13 gals.	88.6	94.4	75.7
Aldrin, 8 oz./7 gals.	98.9	92.5	35.2
DDT, 2 lbs./13 gals.	20.8	23.5	14.2
DDT, 2 lbs./7 gals.	—	60.8	21.4
Toxaphene, 4 lbs./13 gals.	—	48.7	5.1
Chlordane, 1.5 lbs./13 gals.	—	77.2	52.0
Chlordane, 1.5 lbs./7 gals.	—	40.7	28.5
DDT, 2 lbs. 50% W with 50 lbs. nitrate fertilizer applicator	No control	No control	—
TDE, 2 lbs. 50% W with 50 lbs. nitrate fertilizer applicator	15.6	20.6	—

On April 29, 1952, tests for controlling this cutworm were conducted in unreplicated plots ranging in size from 6 to 13 acres in a field near Loveland. Emulsifiable forms of three materials were applied with a low pressure sprayer in 8 gallons of water per acre. Thirty-six hundredths inch rain occurred a few hours after the sprays had been applied. The insecticides were not harrowed into the top soil. Most of the cutworms were in the 4th or 5th instars. Examination at 8 and 15 days gave the results as shown in table 2.

On May 13, TDE 2 lbs. or dieldrin 8 oz. per acre were applied to an 8-acre field in which the barley plants had been completely destroyed by 6th and 7th instar larvae. A low pressure sprayer applied 8 gallons of spray per acre. The field was harrowed immediately after the spray application, and 0.4 inch rain fell during the night. Examination in 6 days showed a mortality of 80 per cent for the TDE and 96 for the dieldrin. Examination at 15 days showed the TDE caused 94 per cent mortality and dieldrin 99. The cost of each insecticide was approximately $3.00 per acre.

Table 2.—Insecticide tests on pale western cutworms. Loveland, Colorado, 1952.

Insecticides and Rates per Acre	Plot Size, Acres	Average Mortality, Per Cent
Dieldrin, 8 oz./8 gals.	10	87.9
Heptachlor, 8 oz./8 gals.	10	80.5
Lindane, 8 oz./8 gals.	6	59.3
Lindane, 4 oz./8 gals.	13	45.7

[1] Scientific Journal Series No. 414, Colorado Agricultural Experiment Station.

Nature of Food and Its Influence on Rice Weevil

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Kinoshita & Ishikura (1940), Richards (1944), Birch (1946) and others have reported that when rice weevil, *Sitophilus oryzae* (L.), was reared on different grains it differs in size and weight. It was also observed by the senior writer that weevils fed on corn were larger and heavier than those fed on wheat, other conditions being similar. It was believed that this was due to the kind and quality of food. Therefore it was thought desirable to determine what influence the quality of food might have upon the weight of adult rice weevils.

METHODS.—To obtain the same quantity and kind of food, White Federation wheat was used. Equal sized kernels were chosen and a portion of it was boiled in water for one hour then was allowed to dry. The normal and the boiled wheat was brought into equilibrium with 70 per cent relative humidity which resulted in a moisture content of 13.6 per cent for normal wheat and 12.2 per cent for the boiled wheat. Approximately equal quantities of each sample were placed with about equal number of females and were placed at a constant temperature of 26.6° C. and a relative humidity of 70 per cent and after 2 days females were removed and the cultures were left for incubation. After the emergence of weevils the wheat in each culture was replaced with corresponding wheat 1 week after the first weevils emerged and thereafter every 2 weeks for the duration of the experiment. Weevils which emerged from normal and boiled wheat were weighed separately in samples of 75 at varying intervals for 4 months. Each experiment and each weighing was replicated three times.

RESULTS AND CONCLUSIONS.—Weevils emerged in 30 days from normal wheat whereas development was delayed for 3 days in boiled wheat. This is because of the more favourable moisture content of normal wheat for the rapid development of weevils. However, adults developed from boiled wheat are heavier (1.39 mg.) than those reared from normal wheat (1.20 mg.). This occurred despite the fact that the moisture content of normal wheat was more favourable (13.6 per cent) for the development of the weevils than that of the boiled wheat (12.2 per cent). These results are summarized in table 1. Richards (1948) found that granary weevils reared from whole wheat were heavier than those reared from English wheat.

The initial weight of adults from boiled wheat is more than the maximum weight of the adults from normal wheat. The boiling of wheat has resulted in the production of larger and heavier weevils. The per cent increase in the weight of adults in 4 months, however, is slightly more in weevils from normal wheat, because lighter weevils tend to put on more weight.

The heavy weight of weevils reared and fed on boiled wheat is due neither to the influence of temperature nor relative humidity. The difference in the moisture content is negligible and can be disregarded as a factor in producing heavier adults from boiled wheat because the moisture content of boiled wheat is less favourable for weevil development and activity than that of normal wheat. The possibility of the effect of the quantity and the kind of food can be dispensed with for equal quantities of wheat of the same variety were used in both the experiments.

The heavier adults from boiled wheat is probably due to the boiling which might have affected the physical or chemical nature of wheat used as food and the availability of certain nutrients to the weevils.

Table 1.—Influence of nature of food upon rice weevil reared at 26.6° C. and a relative humidity of 70 per cent.

Nature of Wheat	Per Cent Moisture Content	Av. Length of Development (Days)	Weight of Adults in Milligrams		Per Cent Increase in Weight
			Range	Average	
Normal	13.6	30	1.17–1.24	1.20	6
Boiled	12.2	33	1.35–1.42	1.39	5

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Tomosvaryella lepidipes—A Parasite of the Geminate Leafhopper[1]

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The geminate leafhopper, *Colladonus geminatus* (Van D.), is the principal vector of the western X-disease virus of the peach, cherry, and chokecherry in Utah. A high percentage of the adults collected in the late summer (August–September) usually succumb to parasitism by the dorilaid *Tomosvaryella lepidipes* Hardy. At the time of collection by means of sweep net and aspirator there is no evidence of parasitism of the adult leafhoppers. In vector tests the leafhoppers in muslin sleeve cages are placed on the inoculum and test trees, and parasitism is usually first discovered when the leafhoppers are taken from the cages. At this time the parasites are in the pupal stage.

During the fall of 1952 about 30 puparia were taken from cages containing geminate leafhoppers. They were held in a glass vial at room temperature until a dozen of the flies emerged after a rest period of approximately 3 months.

The specimens were identified by D. Elmo Hardy, University of Hawaii, who stated that this is the first host record for *lepidipes*. The species was described by Dr. Hardy in 1943. Dorilaidae commonly

[1] In cooperation with the Utah State Agricultural College and Experiment Station at Logan, Utah.

parasitize leafhoppers, and the members of the family have a wide distribution. Dr. Hardy reports collections of *lepidipes* from Arizona, California, Colorado, Kansas, Nevada, New Mexico, Oklahoma, Pennsylvania, Texas, and Utah in the United States, and from the provinces of British Columbia and Saskatchewan in Canada.

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A Modification of the Huffaker Cage for Confining Mites or Small Insects

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The Huffaker cell, a cage for confining small insects on plant leaves, has been modified so that it is satisfactory for mites belonging to the genus *Typhlodromus*. It was found that these small, rapid moving Acarina could easily escape from the Huffaker cell.

Huffaker's original cage consisted of one piece of plywood and two pieces of plexiglass, each approximately 8.8 cm. by 11.4 cm. (Peterson 1953). A rubber washer 2.5 cm. wide was placed on the plywood and inside the washer, a layer of blotting paper followed by a piece of gauze. Upon the gauze was laid a leaf and upon this one piece of plexiglass with a hole in its center. The cell, or hole, was then sealed by placing a second solid piece of plexiglass over the first one. All parts were held in place by rubber bands. Huffaker (1948) reported that he was able to maintain a leaf in good condition for 3 or 4 weeks providing the blotting paper and gauze were kept moist.

Approximately the same diameters were used in the modified cage. Masonite, 4 mm. thick, was found to be a satisfactory substitute for plywood and had the advantage of being thinner, lighter and easier to cut. Two alternating layers of blotting paper and cellucotton, each 8 mm. thick, were placed on the smooth, water-proofed surface of the masonite. A freshly picked young leaf of a bean plant was placed on the wet cellucotton. A piece of plexiglass with a small hole in it (the size may be varied depending on the problem) was placed on the leaf. To save material and time, two or more cells each not more than 2 cm. in diameter were cut in one piece of plexiglass. The side walls of the cells were beveled by a cone-shaped bit at approximately a 60° angle so that any activity in the cage could be observed readily. A ring of agar was used to close all openings between the plexiglas and the leaf. To prevent spreading of the agar, a heavy wax pencil line was made around and approximately 5 mm. from the edge of the hole. Drops of green colored agar were added, by means of a 21 gauge hypodermic needle, between the wax pencil line and the edge of the cell. The crayon line prevented the agar from flowing over the plexiglass. When the agar was sufficiently congealed, so that it would not drop when the plexiglass was inverted, the plexiglass was placed on the leaf and held in place by rubber bands. Any excess agar which oozed into the cell was removed by a moistened camel's hair brush. Instead of one large piece of plexiglass for a cover, individual pieces of plexiglass, each approximately 5 mm. larger than the cell, were used. These were held in place by metal clips which were fastened to the plexiglass by screws placed in holes slightly smaller than the screws. It was found that a pin-curl clip, purchased at any Five & Ten Cent Store, could be taken apart and made into two fasteners.

In setting up a cage, the cellucotton and blotting paper were thoroughly moistened before the parts were assembled. The moisture content was maintained by periodically dampening the edges of the cage and injecting water next to the leaf by means of a lumbar puncture needle attached to a 10 cc. syringe. By this technique a green leaf could be kept in a normal state for 3 or 4 weeks.

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Transmission of the Oak Wilt Fungus by the Pomace Fly

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In a preliminary experiment performed at the Ohio Agricultural Experiment Station at Wooster, Ohio, a wounded red oak seedling died early in July 1953 from the oak wilt disease following exposure to adults of the pomace fly, *Drosophila melanogaster* Meig. The flies had previously fed and laid eggs upon sporulating mats of *Endoconidiophora fagacearum* Bretz, the fungus that causes oak wilt.

The two year old seedling selected for the experiment was grown from an acorn in the greenhouse and was in a vigorous condition. Several wounds were made artificially on April 25, 1953, by cutting out small wedge-shaped sections of bark and xylem from the seedling stem with a sterilized razor blade. The callus tissue that subsequently grew in the wounds following the cutting operations was also cut with a sterilized razor blade on May 19 and again on May 25, 1953, using care not to penetrate the xylem. No bleeding occurred except that a little moisture formed on the cut edges of the wounds.

Immediately following each of the three cutting operations, partly closed culture dishes containing approximately 200 trapped adults of *Drosophila melanogaster* and mats of *Endoconidiophora fagacearum* were introduced in a cage with the test seedling. The flies had been attracted to the mats and had fed and laid eggs upon them for from 2 to 24 hours previously. In the cage the flies thus had access to both sporulating fungus mats and the seedling wounds upon both of which they were observed to feed. Continued egg laying was observed on the fungus mats after the flies were introduced in the cage. After each of the three introductions, the flies were allowed to remain in the cage until they died about 7 days later when the fungus mats in the partly closed culture dishes were sodden from the feeding of their larval progeny.

The first typical foliar symptoms of the oak wilt disease appeared in a terminal leaf of the test seedling on July 5, 1953, when discoloration, curling and stiffening of the leaf occurred, followed in the

next 5 days by similar foliar disease symptoms in the remaining leaves of the seedling. The seedling was cultured by George Bart of the Botany and Plant Pathology Department on July 10, 1953, and one week later *Endoconidiophora fagacearum* was found growing from numerous chips taken from the stem and root.

Sugar-Beet Wireworm Predaceous on Seed-Corn Maggot

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With the recent widespread use of soil insecticides for the control of the sugar-beet wireworm, *Limonius californicus* Mann., in lima bean fields in southern California, there has been a noticeable increase in populations of the seed-corn maggot, *Hylemya cilicrura* (Rond.), and its damage to sprouting lima beans.

In June 1946 the writer's attention was called to maggot damage in a 40-acre field of lima beans that had been fumigated for wireworm control 6 days prior to planting. The cotyledons of the emerged beans had been severely damaged by the maggots.

To obtain an idea of maggot abundance, ten soil samples 3 feet long, 4 inches wide, and 6 inches deep were taken at random in the bean rows and sifted to recover the seed-corn maggots present. In these samples 32 larvae and 60 pupae were found, or an average of 3.1 larvae and pupae per foot of row, but no wireworms. In an adjacent untreated field there were the usual damaged or dying plants with wireworms present in the stems, but only an occasional plant with typical injury to the cotyledons due to maggots.

It had been suspected in previous years that sugar-beet wireworms were predaceous on seed-corn maggots. The cannibalistic tendencies of these wireworms were evident when they were being reared in outdoor cages (Stone 1941). Thomas (1940) lists a number of elaterids that are not only cannibalistic, but also predaceous on certain other insects. Both maggots and wireworms feed on the interior portions of the sprouting beans and tunnel into the underground portion of the stems and upward. Maggots in these locations would be extremely vulnerable to attack by wireworms.

In 1946 five seed-corn maggot larvae or pupae were confined in each of eleven 4-ounce salve cans filled with moist soil, with lima beans for food, and five sugar-beet wireworms. Three cans each containing five maggot larvae or pupae only served as checks. After 13 days the soil in each can was examined. Only 15 per cent of the maggots confined with wireworms survived, as compared with 100-per cent survival in the containers without wireworms. Although the wireworms were not seen feeding on the maggots, the results indicate that the sugar-beet wireworm is predaceous on the seed-corn maggot.

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Occurrence of the Vetch Bruchid in Lentil Seed

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During the fall of 1951 weevils were found in lentil seed grown near Farmington, Wash., which were determined as the vetch bruchid, *Bruchus brachialis* Fahr., by W. H. Anderson, Division of Insect Detection and Identification of the Bureau of Entomology and Plant Quarantine.

Of 88 samples of lentil seed examined in 1951 by the Production and Marketing administration in cooperation with the University of Idaho, 13 were infested. In these samples the infestation ranged from 0.03 to 0.4 per cent. No infested lentil seed could be found in 1952, although the bruchid was generally distributed over the lentil-growing area of Washington and Idaho, where about 15,000 acres are grown.

Numerous fields of lentils were swept for the vetch bruchid in 1952. Adults were found only in parts of fields where volunteer vetch was growing. Even where the weevils were numerous in adjoining patches of vetch, none were found on the lentil plants.

The presence of the vetch bruchid in lentil seed in 1951 is attributed to a weed-control program that year, by which the weevils on volunteer vetch in the lentil fields were deprived of vetch seed pods on which to lay their eggs. The vetch plants either had been delayed in developing seed by late cultivation or were killed by herbicide sprays. Apparently the weevils were forced to attack the lentil seed.

[1] In cooperation with the University of Idaho Agricultural Experiment Station.

Miccotrogus picirostris (Fab.) Found on Red Clover in New York

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No verified record of *Miccotrogus picirostris* (Fab.) has ever been reported east of Ohio in the United States although specimens of this weevil are taken readily from alsike clover in Ontario in areas just north of parts of New York. It seemed highly probable therefore that if the weevil existed in Ohio, west of New York, and in Ontario, just north of New York, it was very likely also to be found in New York. Therefore in the summer of 1952 an intensive search was made of alsike and medium red clover in counties nearest to these areas, outside of the state, known to be infested with *Miccotrogus picirostris*. In Oswego county, which borders on Lake Ontario, both *M. picirostris* (Fab.) and *Tychius stephensi* Schönh were readily taken in sweeps and hand collections from blooms of medium red clover during the month of August. While *Miccotrogus picirostris* (Fab.) were taken from red clover it is not known whether these insects were merely resting on these plants or whether they were actually feeding on red clover. More work is necessary to determine if *M. picirostris* will feed and can be reared on red clover and also to determine its exact distribution in the state.

This record of *Miccotrogus picirostris* is believed to be the first verified record of this insect in New York. Detwiler (1923), in an early paper, reported *M. (Tychius) picirostris* from New York but from his

description of the insect and details of its life history it is believed that his insect was *Tychius stephensi* Schönh. a similarly appearing insect which had been confused for many years with *M. picirostris*. Unfortunately, there are no specimens of Detwiler's weevils available in the Cornell University collection to verify his earlier identifications. In personal correspondence with Dr. Detwiler, he too believes that his earlier identification, though correct at that time, is now in error in light of our present knowledge of the taxonomy of these two similar appearing insects.

ACKNOWLEDGMENTS.—The authors wish to thank Dr. Henry Dietrich, Curator of the Insect Collection at Cornell University, who first identified the first five specimens of *Miccotrogus picirostris* (Fab.) and Miss Rose E. Warner of Division of Insect Detection and Identification of the U. S. Bureau of Entomology and Plant Quarantine who confirmed this identification.

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A Method for Rearing the Onion Maggot in Insectary Cultures

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To further field research on the onion maggot, *Hylemya antiqua* (Meig.), it has been desirable to have an abundant supply of eggs and larvae for insectary experiments. A search of the literature revealed a paucity of information on maintaining insectary cultures other than rearing methods used in life history studies. Several attempts were made to increase a population of flies in cages but each ended in failure. Adults were collected from the field or reared from larvae found in onion bulbs and placed in a large cage with potted onion sets for egg laying. Few eggs were produced. They were fertile which gave encouragement to continue.

The lack of proper nutriment appeared to be an obvious reason for the failure of the flies to oviposit because the adults lived for long periods in the cage. Without prior knowledge of the dietary needs of the flies the search for the necessary nutrients to induce oviposition was by trial and error.

The flies have often been observed in the field visiting flowers of weeds growing near onion fields. Hence various flowering plants were placed in the cage. Although the flies appeared to feed in the blossoms egg deposition continued to be light. Honey diluted with equal parts of water was then offered. However, the solution fermented quickly and fly mortality increased sharply indicating a toxicity associated with the fermented mixture. Undiluted honey was then used and the flies appeared to feed but still failed to lay eggs. With more hopes than logic brewers yeast was added to the menu. Within a short time the flies were noted feeding on both honey and yeast. Copious egg deposition followed. Since employing this method no trouble has been encountered in rearing this insect.

The culture is maintained in the insectary in a cage approximating 4 feet on each side. The framework is covered with a fine mesh cloth stapled to the wood. Crevices between wood and cloth should be avoided as the flies crawl into the spaces and become lodged. Food provided in small open vessels, is renewed at weekly intervals. For oviposition sites, onion sets are planted in moist soil in a shallow clay platter 6 to 8 inches in diameter. The eggs are laid in abundance around the small bulbs and between the loose scales of the bulbs.

To obtain larvae and pupae in abundance the soil containing eggs is transferred to 10-inch pots, placing large onion bulbs on the soil surface as food for the larvae. When the larvae have pupated the soil mass is washed through a 16-mesh wire cloth which retains the pupae. Pupae and the debris remaining on the screen may be separated by floating the pupae in a pail of water. The pupae are then skimmed from the water, placed in a clay platter and covered with vermiculite. Shortly the flies will emerge and in this manner the culture may be maintained indefinitely.

The Seasonal Cycle of the Strawberry Rootworm, *Paria canella* (Fabr.) in North Carolina[1]

STELMON E. BENNETT,[2] and B. B. FULTON, *North Carolina State College, Raleigh*

This study was conducted to determine whether the strawberry rootworm passes thru one or two generations per year in North Carolina. It was known that adults emerged from hibernation in the spring and that they increased in numbers about mid-July. This sudden increase was assumed to be due to the maturing adults of the first generation from eggs laid in the spring. If this increase consisted of over-wintered adults, their late appearance would remain unexplained. The period from mid-July until cold weather seemed long enough for the development of a second generation in North Carolina.

Research on the life history was started in October of 1950 and carried through to December, 1951, with some additional work in the summer of 1952. The beetles were kept in covered glass dishes, with a few strawberry leaves for food. Eggs were deposited where the leaves and glass came in contact or between pairs of glass microscope slides separated at one end by an insect pin as described by Smith and Kido (1949). The larvae were reared in the same dishes with strawberry leaves for food. When about to pupate they were removed to moist soil in salve boxes.

It was found that the strawberry rootworm in North Carolina has one generation and a partial second generation each year. The overwintering form is the adult. The majority of adults hibernate in the strawberry fields, where they hide under the matted dead leaves in the row, or in the loose soil around the plants. Some beetles, however, hibernate in fields and woods adjacent to strawberry fields, among dead leaves and clump-forming grasses.

Early in the spring the adults become active, feed and begin laying eggs. The first recorded date of egg laying in the laboratory was April 17, 1951. Oviposition continued until mid-July, the peak being in the latter part of May and first few days in June.

The first egg hatched on April 25, 1951. The average period of time passed in the four larval instars

[1] Published with the approval of the Director of the North Carolina Agricultural Experiment Station as paper No. 490 of the journal series.

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was 47 days. The peak of larval population occurred about the latter part of June. The larval stage continued until September 12. The pupal stage began about mid-June and continued until September.

First generation adults began to emerge in mid-July and reached a peak about the last of July. At least some of these adults are thought to live until the following June or July or longer, but no records of longevity have been kept in North Carolina. The species is usually considered univoltine (Smith & Kido 1949). From mid-July until the time when they enter hibernation, a large number of adults are found in strawberry fields. In the spring after emergence from hibernation adults are usually scarce in the field. This may be due to high winter mortality occasioned by natural enemies and weather conditions.

The average number of days to complete the immature stages of laboratory reared specimens of the first generation were as follows:

Egg	7.8
1st larval instar	11.3
2nd larval instar	10.3
3rd larval instar	12.6
4th larval instar	13.3
pupa	7.8

A few beetles of the reared first generation deposited eggs forming a partial second generation. Larvae hatching from these eggs were placed on potted strawberry plants, each plant covered with a wire screen cylindrical cage. These plants were kept out of doors and examined frequently for the emergence of beetles in the cages. Since no beetles had appeared by December, 1951, the plants were taken up and the dirt sifted. Nine rootworms were found, all in the pupal stage.

One individual of the second generation was reared to maturity in the laboratory. The time required to complete the life cycle of this individual was somewhat longer than for the first generation. The time recorded for the various stages was as follows:

Egg	Aug. 6–13, 1951
1st larval instar	Aug. 13–22
2nd larval instar	Aug. 22–Sept. 5
3rd larval instar	Sept. 5–17
4th larval instar	Sept. 17–Oct. 2
pupa	Oct. 2–19
adult	Oct. 19, 1951–May 30, 1952

This beetle, which was reared by itself, deposited some eggs about May 22, 1952, and by May 30, the eggs had hatched, thus demonstrating parthenogenesis. Smith and Kido (1949) claim that all beetles are females in the Santa Clara Valley, California. In North Carolina, a few males have been found as revealed by dissection.

Some information on the probable proportion of first generation beetles giving rise to second generation larvae, was gained in the summer of 1952. Twenty-eight beetles were collected on June 10, near Wallace, North Carolina, and segregated in individual covered dishes containing strawberry leaves. These were collected before the summer increase in beetle population and were probably all of the over-wintering brood. Twenty of the beetles laid eggs within 10 days and the other 8 died. Dissection showed that all were females.

On July 24, after the mid-summer increase in beetle population, about 130 beetles were collected near Wallace. One hundred of these were dissected to determine the sex and the presence of fully developed eggs. Only 4 were males and 72 of the 96 females had eggs present.

The remaining beetles were kept for a week in a jar with strawberry leaves and on August 7, 25 were placed in individual dishes. Within 6 days, 17 of the 25 laid eggs while the remainder never deposited any eggs although kept in dishes more than 2 weeks. The proportion depositing eggs for a partial second generation was 68 per cent, which is close to the 72 per cent found by dissection to have well developed eggs.

If 68 to 72 per cent represents a normal proportion of beetles giving rise to a second generation, it is surprising that more damage due to larval feeding has not been observed in late summer. Most of the injury to strawberry plants has been attributed to adult feeding, for even where this is severe, it is often difficult to find any larvae or injury to the roots.

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A Simple Method of Collecting Spider Mites

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The usual methods of securing plant-inhabiting mite specimens are either time consuming or are apt to result in overlooking light infestations. Leaves suspected of harboring mites are often beaten into a white or black pan through a piece of hardware cloth, and the mites are individually picked from the pan, or the plant specimens are examined with a hand lens or taken into the laboratory and examined with a microscope and the mites are picked from the leaves. Many casual collectors take only the larger specimens, overlooking the smaller males, which are necessary for precise identification of most tetranychid mites.

The method of collection here described is rapid, simple, permits sampling large amounts of plant material, collects the mites directly into preservative without microscopic examination and almost always results in securing males, even from very light infestations.

The apparatus consists of a screen fastened over the large end of a funnel. Plant material is beaten vigorously on the screen, and the mites which pass through are funnelled into a suitable container supported below the narrow end of the funnel. In the laboratory the first few mites may be collected in a dry watchglass for microscopic observation of the live mites. The rest can be collected in another dish containing 70 per cent alcohol. In the field a vial of suitable size containing preservative may be fastened temporarily to the short funnel stem with cellophane adhesive tape while making a collection, or a rubber stopper having a suitable hole may be slipped over the stem of the funnel and the vial placed over this while collecting.

Construction details may vary from simply fastening a circle of plastic window screen in wooden embroidery hoops by means of wire staples, to soldering a circle of copper screen to a circle of heavy wire, of a size to fit over the large end of a 150 mm. glass funnel. A more rugged device for field use might em-

ploy a metal funnel with a very smooth surface (such as stainless steel, or chrome plate) to which the screen is fastened by soldering on a hinge for lifting the screen and cleaning the device between collections. The funnel stem should be very short to facilitate cleaning. Mites left on the device from previous collections should be completely removed to avoid mixing them with those of other collections. A small bottle brush and a clean cloth are used for cleaning. Tapping the funnel after beating the leaves will dislodge most of the mites clinging to the funnel and they will fall into the collecting dish.

The use of this funnel is not limited to making collections from foliage for taxonomic purposes. It may be used for rapidly surveying a test plot for the first appearance of mites, or for their persistence or disappearance after treatment with acaricides, and for making population counts. For instance, the average number of mites per leaf on cotton can be quickly estimated by collecting the mites from a number of leaves on one or several plants and counting the mites collected in a small dish in a short time. More nearly accurate counts will be achieved if the screen is sharply tapped after beating the leaves, and the mites clinging to the inside of the funnel are gently brushed downwards into the narrow neck with a camel's-hair brush.

The Establishment in California of an Oriental Strain of *Prospaltella perniciosi* Tower on the California Red Scale

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In 1949, J. L. Gressitt of this Department and his assistants, Y. W. Djou and T. C. Maa, made a large series of shipments of diaspine scale material from Formosa and China. From various shipments a few specimens of a *Prospaltella* designated originally as "F" were propagated readily by S. E. Flanders on the California red scale, *Aonidiella aurantii* (Mask.), in quarantine. This species was subsequently determined by Harold Compere to be morphologically indistinguishable from *Prospaltella perniciosi* Tower, the well known San Jose scale parasite. Flanders propagated large numbers of this species during 1949 and colonizations were made by the author and county agencies throughout the red scale infested areas of southern California. Smith and Flanders (1950) reported that this parasite had reproduced at least one generation in the field.

A survey of Los Angeles County citrus groves in 1951, which had been colonized with *Prospaltella perniciosi* in 1949, showed that definite establishment had occurred in certain untreated groves.

Since 1949 the progress of this species has been regularly followed in several untreated study plots. These represent both coastal and interior conditions. *Prospaltella* has successfully maintained itself from 1949 to 1953 under both sets of conditions. In most cases this parasite has had to compete with well established natural *Aphytis* populations and in certain cases with periodic colonizations of large numbers of *Aphytis*. That it has been able to survive the latter conditions is remarkable.

Prospaltella perniciosi gives promise of becoming a valuable adjunct to *Aphytis* in the quest for biological control of the red scale. It appears more important than *Comperiella bifasciata* (Chinese strain) as a parasite of the California red scale where the two coexist. Following a colonization of 100 females in May 1949, in one coastal Orange County plot, *Prospaltella* was found to be more abundant in November 1952 than was *Aphytis* in the original colonization area even though *Aphytis* had maintained the red scale at a low level in this grove for years past. In one untreated Los Angeles County plot (interior) each tree of which has received 4000 *Aphytis* "A" per year, *Prospaltella* has not only maintained itself but has been the dominant parasite in the late winter and early spring of 1952 and 1953. Inasmuch as *Aphytis* populations are generally at their lowest ebb during this period of the year, due to unfavorable meteorological conditions, *Prospaltella* may well fill an important niche in the natural control or mass-colonization-induced biological control of the red scale. The effects of periodic mass colonization of *Prospaltella* in control of red scale are now being investigated.

This case reemphasizes the importance of importing and colonizing every available natural enemy of a given pest regardless of its specific taxonomic standing or its supposed importance or unimportance in the country of origin. In spite of intensive search for California red scale parasites in the Orient covering 50 years no notice or mention of this parasite occurred previous to the arrival in Riverside in 1949 of a few individuals in scales from Formosa and China. Nearly all past efforts had been directed toward obtaining *Comperiella bifasciata*, an abundant and easily observed parasite of the California red (Chinese strain) and yellow scales (Japanese strain) in the Orient. As it appears now, *Prospaltella* is destined to become a greater cause of red scale mortality in southern California than is *Comperiella*.

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Combinations of Insecticides for Control of the Pink Bollworm and Other Cotton Insects in the Lower Rio Grande Valley

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A search has long been underway for one insecticide or a combination of two insecticides that will control all the principal cotton insects. Since no promising single material was found, attention was focused on combinations of materials.

Heavy infestations of both the pink bollworm, *Pectinophora gossypiella* (Saund.), and the boll weevil, *Anthonomus grandis* Boh., in the Lower Rio Grande Valley of Texas in 1952 afforded a good opportunity for field tests to be conducted for the control of both these insects. At the same time information was obtained on the effectiveness of the materials against the bollworm, *Heliothis armigera* (Hbn.), the cotton aphid, *Aphis gossypii* Glov., the

[1] U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine, in cooperation with the Texas Agricultural Experiment Station.

Table 1.—Effectiveness of combinations of insecticides in sprays for control of pink bollworm in the Lower Rio Grande Valley in 1952.

Test No.	Number of Applications	Per Cent of Blooms Infested	Bolls			Yield, Pounds per Acre	
			Number Examined	Per Cent Infested	Number of Larvae per Infested Boll	Total	Gain Over Check
DDT 1–1.5 pounds plus methyl parathion 0.2–0.375 pound per acre[1]							
1	8	0.1	900	9.0	1.2	—	—
2	11	3.7	800	16.4	1.3	1447	1049
3	7	1.2	700	17.9	1.5	1875	1600
4	7	1.8	700	15.6	1.4	2020	900
5	8	3.6	900	22.3	1.5	—	—
6	3	0.5	600	14.0	1.4	—	—
Av.	—	1.7	—	15.7	1.4	1781	1183
DDT 1–1.5 pounds plus Metacide 0.2–0.375 pound per acre[1]							
1	8	0	900	12.4	1.6	—	—
2	11	2.3	800	14.8	1.5	1460	1062
3	7	1.9	700	17.4	1.6	1985	1710
4	7	2.9	700	11.1	1.4	1880	760
5	8	1.3	900	17.2	1.5	—	—
6	3	1.5	600	16.5	1.4	—	—
Av.	—	2.0	—	14.9	1.5	1775	1177
Untreated check							
1	—	0.8	900	63.1	3.1	—	—
2	—	17.5	800	71.5	3.1	398	—
3	—	9.4	700	77.9	3.8	275	—
4	—	8.0	700	37.1	2.1	1120	—
5	—	7.4	900	63.8	3.1	—	—
6	—	2.3	600	49.7	2.7	—	—
Av.	—	8.1	—	61.2	3.0	598	—

[1] Dieldrin at 0.375 pound per acre added in last two applications in test No. 2 and in the final application in Nos. 3, 4, and 5.

cotton leafworm, *Alabama argillacea* (Hbn.), and spider mites (Tetranychidae).

MATERIALS AND METHODS.—DDT was used in combination with methyl parathion or Metacide. Dieldrin was added in some of the treatments. All materials were applied as emulsion sprays. Six tests were made of each mixture, with a single plot for each test. The treated plots in five of the tests averaged about 3.6 acres, and the untreated plots, 1.5 acres. The plots in the sixth test were not measured. Most of them were located fairly close to San Benito, Texas.

Methyl parathion and Metacide were applied at approximately 0.20 to 0.375 pound per acre, the lowest dosage being used early in the season when the cotton was small. Sufficient DDT was added at the time of application to give approximately 1 pound per acre for the first three applications and 1.5 pounds thereafter.

Sufficient dieldrin to give 0.375 pound per acre was added in the last two applications in test No. 2 and in the final applications in Nos. 3, 4, and 5, for control of the boll weevil after this insect had begun to migrate.

Most of the applications were made with 8-row trailer-tractor sprayers. The machines were equipped with two nozzles per row, and operated at a pressure of about 60 pounds per square inch so as to give approximately 5 gallons of spray per acre. Applications that could not be made with the tractor equipment were made with hand sprayers in as nearly the same manner as possible.

The applications were begun during the first week of blooming, when 10 per cent or more of the blooms were infested with pink bollworms. They were repeated as nearly as possible at weekly intervals until the crop was matured, except after the third effective application, when the interval was extended to 2 weeks. It was thought that a longer interval could be used at that time, because the first bolls were subject to the least damage from the pink bollworm and time and expense could be saved. All applications were made between April 15 and July 3.

Counts of pink bollworms in bolls were made at about weekly intervals, 100 bolls being examined per plot for each record.

RESULTS.—Table 1 summarizes the pink bollworm infestation in blooms and bolls for each of the six tests with sprays containing the two combinations of insecticides, and yields in three of them that were comparable. Boll weevil infestations were not recorded, but regular observations indicated that the damage caused by this insect was about equal to that caused by the pink bollworm. Both combinations appreciably reduced the number of blooms and bolls infested with the pink bollworm, and the number of larvae per infested boll. There was practically no difference in the results between them.

All treatments were effective against the boll weevil up to the time of migration. The addition of dieldrin in the final applications gave good control of this insect. Both mixtures gave substantial reductions in the number of bolls infested and in the number of pink bollworm larvae per infested boll. There was practically no difference in the results between the two mixtures.

Conditions were suitable for yield records to be made in only three of the tests, since rain washed off one application in test Nos. 1 and 5 and two in No. 6. In these tests both mixtures increased the yield

to almost twice that in the untreated plots. The gains may be attributed about equally to the control of the pink bollworm and the boll weevil.

Cotton aphids, bollworms, cotton leafworm, and spider mites were also held in check with the combinations of insecticides. Both methyl parathion and Metacide are promising materials, but the former would probably be preferable, since it is a little more effective against the boll weevil.

The Dehydrochlorination of DDT by Resistant Cockroaches

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It has been reported from several laboratories that insecticide-resistant house flies, *Musca domestica* L., dehydrochlorinate DDT at a greater rate than do susceptible strains, although the exact relationship to resistance is not clear (Chadwick 1952). With the availability of a strain of German cockroaches, *Blattella germanica* (L.), highly resistant to chlordane and moderately resistant to certain other insecticides (Heal *et al.* 1952), experiments were conducted to learn whether this strain also was able to dehydrochlorinate DDT faster than a strain of susceptible roaches.

The ancestors of the resistant insects were collected in the field five generations previously, and successive generations have been reared in the laboratory according to the procedure described by Piquett *et al.* (1952) without exposure to insecticide. The susceptible insects were kindly furnished by P. G. Piquett from his normal laboratory colony.

Adult male roaches of approximately the same age were narcotized with carbon dioxide, and 1.08 cubic millimeters of an acetone solution containing 5 micrograms of pure *p,p'*-DDT was applied topically to the thorax with a micrometer-driven syringe (Trevan 1922). To avoid leakage the syringe plunger was lightly greased with silicone-type stopcock grease. The treated roaches were then placed in beakers with food and water and held for 48 hours. Seven roaches were used for each test with six replications.

The dead insects were rinsed with acetone to remove external DDT, and ground with anhydrous sodium sulfate. Only a few insects died as a result of the treatment, owing to the slow rate at which DDT kills roaches, 10 days being the usual time at which mortalities are observed when maximum kill is to be determined. The dead insects from the several replications were pooled for analysis.

The live insects were anesthetized with ether, rinsed with acetone to remove external DDT, and ground with anhydrous sodium sulfate. Acetone was also used to rinse the beakers in which the insects had been held. The ground tissues were extracted with freshly distilled ether and filtered, and the extracts evaporated in vacuo at room temperature, as were the external acetone extracts. The residues were then analyzed for DDT and DDE, as described by Perry & Hoskins (1951). The results of the analyses are shown in table 1.

From the data in table 1 it appears that at least one strain of resistant German roaches absorbed in 48 hours more DDT than a susceptible strain, and at the same time dehydrochlorinated more of the absorbed DDT. Judging from the total amount of extracted material that responded to the analytical procedure used, to a considerable degree both strains metabolize the absorbed DDT to some other as yet unknown metabolite.

Table 1.—Micrograms of DDT and DDE recovered from German cockroaches 48 hours after topical treatment with 5 micrograms of DDT per roach.

Strain	External		Internal		Unaccounted for
	DDT	DDE	DDT	DDE	
Live roaches:					
Suceptible	2.360	0	0.540	0.113	1.981
Resistent	1.802	0	0.411	0.133	2.634
Dead roaches:					
Suceptible	2.486	0	0.870	0.085	1.546
Resistant	1.896	0	1.050	0.199	1.825

[1] Acknowledgment is made to Michele Williams for valuable technical assistance.

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Control of Rice Weevil in Corn with Protectant Dusts and Sprays

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There has been considerable interest in the use of synergized pyrethrins formulations for control of insects in stored corn in Alabama for the past few years. The possibility of the use of such preparations was revealed with Dove's report (1948) that 100 mg. of piperonyl butoxide and 5 mg. of pyrethrins per square foot gave residual action against the housefly, *Musca domestica* L., for 131 days. Watts and Berlin (1950) reported that formulations of pyrethrins and piperonyl butoxide in four different combinations gave from good to complete control of rice weevil, *Sitophilus oryza* (L.), in wheat. White (1952) found that 75 pounds per 1,000 bushels of a dust containing 0.08 per cent pyrethrins and 1.1 per cent piperonyl butoxide was effective in preventing the build-up of insects in stored wheat. Wilbur (1952) also reported that the use of 0.08 per cent pyrethrins and 1.1 per cent piperonyl butoxide was effective in stored wheat.

Experiments have been conducted for 2 years in Alabama on control of the rice weevil in stored corn

Table 1.—Effect of pyrethrins-piperonyl butoxide dust treatment on rice weevil damage to corn. Camp Hill, Alabama. 1951–1952.

Treatment	Per Cent of Kernels Damaged 9 Months After Treatment		
	1951	1952	2-Year Mean
Corn in shuck			
No treatment	31.21	40.25	37.73
Treated	26.94	23.26	25.10
Shucked corn			
No treatment	43.63	98.89	71.26
Treated	19.78	21.37	20.76
Shelled corn			
No treatment	73.75	98.42	86.09
Treated	5.90	20.38	13.14

with synergized pyrethrins formulations. Results of the experiments are presented in this paper.

Protectant Dusts.—Experiments were conducted in 1951 and 1952 at the Piedmont Substation at Camp Hill with a dust formulation.[1] that contained 0.05 per cent pyrethrins and 0.8 per cent piperonyl butoxide. The dust was applied to Dixie 18 hybrid corn in the shuck, to ear corn with the shuck removed, and to shelled corn. The treatments were replicated 4 times on one-bushel samples of corn. The samples were stored in pasteboard drums covered with 0.25-inch wire screen which prevented the entrance of mice but allowed free ingress and egress of the rice weevil. The samples were stored for 9 months in a corn crib with other corn which was untreated. At the end of the storage period, the samples were shelled, mixed, and weevil damage determined by the acid fuchsin stain method of Frankenfeld (1948).

In 1951 the average kernel damage at the time the test was started was 5 per cent. The moisture content was not measured, but it was estimated to be 10 per cent. The rates of treatment were 1 pound of dust to 8 bushels of corn in the shuck, 1 pound to 10 bushels of shucked ear corn, and 1 pound to 16 bushels of shelled corn. In 1952 the average kernel damage when the experiment began was 5.2 per cent. The moisture content of the corn was 9.7 per cent. All treatments received dust at the rate of 1 pound to 10 bushels.

Results of the experiments are presented in table 1. The dust protectant was effective in preventing damage in the shelled corn. The average damage at the end of the storage periods in the shelled untreated corn was 86.1 per cent of the kernels. It was 13.1 per cent in the treated corn. The protectant provided a fair degree of protection to the shucked ear corn. The 2-year average damage in the untreated shucked ear corn was 71.3 per cent of the kernels at the end of the storage periods; it was 20.8 in the treated corn. In the corn in the shuck there was only a slight reduction in weevil damage due to the treatment.

Protectant Sprays.—An experiment was conducted in 1952 with several spray formulations[2] on control of the rice weevil in stored corn. The experiment included four formulations of pyrethrins and one of allethrin, all of which were synergized with piperonyl butoxide. The treatments were applied to 1 bushel samples of shucked and unshucked Tennessee 10 hybrid ear corn. Treatments were replicated 4 times. The corn contained 12.5 per cent moisture and had 6 per cent of the kernels damaged by rice weevil when the experiment was begun. The experiment consisted of 12 treatments; 6 were on corn in the shuck and 6 were on shucked corn. The sprays were applied to the corn with a small electric sprayer; 90 ml. of spray was applied per bushel of corn. After the treatments were applied, the samples were placed in open-mesh cabbage bags, piled together indiscriminately, and stored for 8 months. At the end of the storage period the corn was shelled, mixed, and samples taken for determination of weevil damage. The acid fuchsin stain method was used for determining the weevil damage.

Results of the experiment are presented in table 2. The rice weevil damage in the untreated shucked corn was 26.2 per cent. None of the treatments significantly reduced the weevil damage below this figure. The weevil damage in the untreated corn in the shuck was 21.2 per cent. None of the sprays significantly reduced the weevil damage below this level.

Table 2.—Effect of several pyrenone spray formulations on rice weevil damage in shucked and unshucked ear corn. Auburn, Alabama. 1952.

Treatment	Per Cent Damage 8 Months After Treatment[1]	
	Shucked Corn	Corn in Shuck
1. Untreated	26.21	21.23
2. 10% Piperonyl butoxide and 1% pyrethrins, emulsifiable; diluted 1–19 with water	30.04	22.24
3. 10% Piperonyl butoxide and 2% allethrin, emulsifiable; diluted 1–19 with water	20.60	18.62
4. 10% Piperonyl butoxide and 1% pyrethrins, wettable powder; 1 lb. to 2.5 gal. water	25.29	18.75
5. 4% Piperonyl butoxide and 0.5% pyrethrins, oil solution; diluted 1–9 with water[2]	25.92	18.63
6. Same as No. 5; diluted 1–9 with mineral oil[3]	18.19	21.02

[1] Differences were not significant at the 5 per cent level.
[2] Five per cent Atlox G-2090 emulsifier added to the oil solution.
[3] Carnation mineral oil.

Summary.—Experiments were conducted for 2 years on control of the rice weevil, *Sitophilus oryza* (L.), in stored corn with protectant dusts, and for 1 year with protectant sprays. A protectant dust containing 0.05 per cent pyrethrins and 0.8 per cent piperonyl butoxide applied at the rate of 1 pound to 10 bushels of corn was effective in preventing weevil damage for 9 months, on lightly infested, low-moisture, shelled and shucked ear corn. On corn in the

[1] Pyrenone Grain Protectant which was provided by the U. S. Industrial Chemicals Co.
[2] Experimental formulations were provided by the U. S. Industrial Chemical Co.

shuck there was only a slight reduction in weevil damage due to the treatment. Pyrethrins-piperonyl butoxide and allethrin-piperonyl butoxide sprays on shucked ear corn and corn in the shuck were ineffective in preventing rice weevil damage.

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Correction of Identity of the Douglas-Fir Cone Moth

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For more than forty years there has been confusion in the literature as to whether one or two genera of moths of the family Olethreutidae bore in cones of Douglas-fir. Essig (1926) reported *Barbara colfaxiana* (Kearfott) (*Evetria*) and its varieties *taxifoliella* (Busck) and *coloradensis* (Heinrich), and the aberrant form *ulteriorana* (Heinrich) as infesting the cones of Douglas-fir in California, Oregon, Washington, and British Columbia, and also the "Douglas-fir cone moth," *Zeiraphera diniana* (Guenée) (*Enarmonia pseudotsugana* (Kearfott)). The same two genera were reported as infesting Douglas-fir cones by Doane, Van Dyke, Chamberlin, and Burke (1936). All biological and taxonomic evidence shows that only one genus, *Barbara*, is involved and that the report of *Zeiraphera* occurring in Douglas-fir cones is in error. The evidence in support of this needed correction is as follows:

The quotations in the literature mentioned and others refer to a bulletin entitled "The Douglas Spruce Cone Moth" by Cooley (1908). In this bulletin, Cooley described the work of a lepidopterous cone borer of Douglas-fir and identified it as *Cydia pseudotsugana* Kearfott. This species was described by Kearfott (1904) from "twenty-three specimens collected by Dr. Dyar at Kaslo and Kokanee Mt. (British Columbia) and taken torpid on the snow of Kitchener Glacier about August 10; also bred by him from larvae taken June 24 on *Pseudotsuga* sp." However, from Cooley's description of the work of this cone moth and from his plate showing an egg on a cone bract, damaged cones and seeds, and especially his picture of the adult moth, the indications are clear that he was not dealing with *Cydia pseudotsugana* but with *Barbara colfaxiana taxifoliella*.

Between 1912 and 1917 J. M. Miller, J. E. Patterson, and the writer made extensive studies at the Ashland, Oregon, laboratory of the U. S. Bureau of Entomology, of Douglas-fir cone-boring insects and particularly of the Douglas-fir cone moth, at that time identified by A. Busck and C. Heinrich as *Evetria taxifoliella* Busck. From 74 rearings of Douglas-fir cone insects from all parts of the Pacific Northwest, California, and the Northern Rocky Mountain region, the Douglas-fir cone-boring moth was always identified as *E. taxifoliella*, although some varietal and regional differences were observed. *Evetria taxifoliella* was described by Busck (1914) from specimens reared by J. Brunner from cones of *Pseudotsuga taxifolia* from Missoula, Montana—the same general locality from which Cooley obtained his specimens.

Heinrich (1920) reviewed the fir cone-boring species of Olethreutidae and from the mass of material reared at the Ashland Laboratory came to the conclusion that most of the moths were varieties of *Evetria colfaxiana*, a species described by Kearfott (1907) from Colfax, Placer County, California. Busck's species *E. taxifoliella* from Montana was reduced by Heinrich to a variety of *E. colfaxiana*. A new variety, *E. colfaxiana coloradensis* Heinrich, was established and also a new species, *Evetria ulteriorana* Heinrich, which was considered as possibly an extreme variety of *E. colfaxiana*.

Heinrich (1923) revised the family Olethreutidae and established a new genus *Barbara* to include all these fir cone-boring moths. *Evetria colfaxiana* became the genotype. Heinrich's work definitely established the fact that all these Douglas-fir cone-boring moths were species or varieties of the new genus *Barbara*. As to *Cydia pseudotsugana*, Heinrich (p. 171) states: "Kearfott's *pseudotsugana* is plainly a synonym of *pinicolana* Zeller. . . . There are no appreciable gentalia differences in the two. The reference to *pinicolana* as a synonym of *diniana* Guenée I have accepted on the authority of the European lists." This synonymy was further verified by Fletcher (1939) who placed *diniana* Guenée, *pinicolana* Zeller, and *pseudotsugana* Kearfott all as synonyms of *griseana* Hubner, which in Europe feeds on *Larix* and *Abies*.

In 1949 a larch budworm defoliated about 90,000 acres of larch and white fir in Washington. This species was identified by J. F. G. Clarke, of the Bureau of Entomology and Plant Quarantine, as the European *Zeiraphera griseana* (Hubner). Thus it appears that *Zeiraphera griseana* (=*Z. diniana* =*Cydia pseudotsugana*) is a defoliator of larch, white fir, and Douglas-fir, and no one, except Cooley, has ever recorded it as boring in cones.

The identity of the Douglas-fir cone moth is clearly *Barbara colfaxiana* and its varieties. The names *Cydia pseudotsugana* and *Zeiraphera diniana* should therefore be dropped as applicable to any of these cone borers.

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Biology of Tabanidae in Florida

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The bloodsucking females of the family Tabanidae are very serious pests of cattle, horses, and other domestic animals. Some of the species of *Chrysops* are also serious pests of man in some localities. Tabanids are of particular economic importance in Florida owing to the large number of lakes, streams, and vast undeveloped swampy areas, which serve as breeding grounds. Another factor contributing to their abundance is the mild weather, which is favorable for adult activity the year around in southern Florida. The ineffectiveness of control methods and the lack of knowledge concerning the species, their distribution, life history, and habits prompted the Bureau of Entomology and Plant Quarantine to enter into a cooperative agreement with the Florida Agricultural Experiment Station in 1950 to investigate these problems.

A survey of the tabanids recorded in publications of Stone (1938), Philip (1947, 1950), Brennan (1935), and Fairchild (1937), together with species collected by the author and determined by Alan Stone, also of the Bureau of Entomology and Plant Quarantine, reveals records of 16 genera comprised of 108 species and subspecies. Ninety of these are in the genera *Tabanus* Linnaeus and *Chrysops* Meigen.

Among the 66 species and subspecies collected during this investigation, only 44 were observed attacking animals; however, the collections were made from buildings, vegetation, and automobiles, as well as from animals. Approximately 25 of these 44 species have been observed in numbers sufficient to be important pests.

SEASONAL OCCURRENCE AND ABUNDANCE.—Adult tabanids are active every month of the year in southern Florida and from March until October in central and northern parts of the State. The period of greatest abundance is from mid-April until the first of October.

Genus *Tabanus* Linnaeus.—Field observations indicate an overlapping of generations in the most widely distributed species of the genus *Tabanus*. *T. atratus* F., *fumipennis* Wied., and *americanus* Forst. appear to have only one generation each year, although the adults may be present at any time from March until October. Heavy populations observed during early and late summer indicate two and possibly three generations of *lineola* F. and *nigrovittatus* Macq. each year. Observations on these two similar species approximate the average 69.9-day life cycle of *lineola* reared by Schwardt (1931) in Arkansas. *Tabanus trijunctus* Walk. produces only one generation per year, and the adults are present for only a month or 6 weeks. However, during this period it is probably the most numerous species. The heaviest population occurs in the Big Cypress Swamp, of Hendry and Collier Counties in the southern part of the State. During May of 1951, a year of extremely light horse fly populations, over 50 individuals of this species were counted feeding at one time on the abdomen of a horse and at least an equal number on other parts of the body.

Genus *Chlorotabanus* Lutz.—The adults of all known infestations of *Chlorotabanus crepuscularis* (Beq.) appear between the latter part of May and the first of July, indicating only one generation per year. An occasional specimen is seen in other localities later in the season, but the species is never numerous. It is an extremely pestiferous feeder for short periods at dawn and dusk, particularly around dairies during milking hours. Several dairymen have stated that they have been forced to cease milking for 30 minutes or longer owing to the attack of this species. The flies bite man as well as livestock.

Genus *Chrysops* Meigen.—Close observations on *Chrysops vittata floridana* Johns. and *pudica* Osten Sacken in north-central Florida indicate two generations each year, one heavy emergence occurring in May and June and another in late August and September. Another species, *C. hinei* Daecke, in central Florida appears to have only one generation, reaching a peak in population during September.

LIFE-HISTORY STUDIES.—*Length of life cycle.*—Laboratory studies of collected material together with specimens reared from eggs reveal that tabanids have an incubation period of 4 to 6 days, a larval period of 220 to 807 days, and a pupal period of 5 to 14 days. Collected adults have lived a maximum of 14 days in captivity.

The life cycles of four species have been studied from oviposition. One specimen of *Tabanus atratus* died in the prepupal stage 224 days after the egg was laid. Two larvae of *T. fumipennis* from the same egg mass pupated when 329 and 334 days old, and the lengths of the pupal periods were 11 and 9 days, respectively. The time from egg to adult averaged 345.5 days. Larvae from another egg mass of this species were kept in a room where a constant temperature of 80° F. and relative humidity of 60 per cent were maintained. One specimen required 381 days from egg to adult, and another died as a larva 807 days after the egg hatched. Seven specimens of *T. endymion* Osten Sacken from a single egg mass completed their life cycle in 259 to 330 days, or an average of 285.7 days. One specimen of *T. rufofrater* Walk. 396 days old died in the pupal stage 10 days after pupating, and another from the same batch died at the age of 684 days, the day after it pupated.

Larval habitat.—The majority of the larvae, in both numbers and species, are found in the top 2 or 3 inches of soil in swamps and around lakes, ponds, and streams that are permanent. A few larvae of species known to prefer soil adjacent to water have been collected in rather dry places; however, those areas without a doubt were inundated or very near water during periods of oviposition. Larvae of *Leucotabanus* Lutz have been collected from decaying logs in wooded areas where standing water would never be found. They have also been taken from a decayed hollow in a living oak tree. The larvae of the genus *Chlorotabanus* seem to prefer a more nearly aquatic habitat than do other larvae. They are commonly found in floating material at the

edge of water, and in one instance they were found abundantly in floating hyacinths several yards from shore. *Tabanus lineola* larvae are frequently found in partially submerged logs.

Larval food.—So far as has been determined, all tabanid larvae in Florida are carnivorous, although other organic material may serve as food. Larvae in the laboratory will accept a variety of foods, including live annelids, insect larvae (even their own species), snails, ground beef, boiled egg yolk, and beef liver. The more abundant invertebrates found in larval habitats include annelids, leeches, snails, tipulid larvae, Odonata naiads, mosquito larvae, and numerous Crustacea, all of which apparently serve as food.

NATURAL ENEMIES.—*Parasites.*—The importance of natural enemies of tabanids in Florida has not been ascertained. However, information obtained during the last 2 years indicates that under favorable conditions certain parasites might be of considerable importance. Hymenopterous parasites reared from egg masses of *Tabanus atratus* were determined as *Telenomus tabanivorus* (Ashm.). Observations on several parasitized and unparasitized egg masses indicate that the parasites reduced the average number of larvae hatching from one egg mass from 686 to 445. Laboratory studies showed that the parasites will deposit their eggs only in fresh egg masses. Adult parasites caged with two fresh egg masses of *T. atratus* immediately began ovipositing. Ten days later the adults began emerging, and by the 12th day the tabanid egg masses had produced 342 and 353 parasites. The masses that would normally produce an average of 686 tabanid larvae did not produce any in these tests. Another species (apparently undescribed), also belonging to the genus *Telenomus*, was reared from an unidentified egg mass.

Only one specimen of a larval parasite has been observed. Its presence in a *Tabanus* larva, unnoticed for 2.5 months, was discovered when it pupated, leaving almost nothing of the tabanid except the exoskeleton. It emerged after 21 days and was determined as *Phasiops flava* Coq., family Larvaevoridae (Tachinidae).

The hymenopterous parasite *Trichopria tabanivora* Fouts was reared from *Tabanus lineola* pupae taken from a partially submerged log near Gainesville, Florida, in 1950. Approximately 100 parasites emerged from each of two pupae.

Predators.—Adult tabanids have a number of predators. The more important ones are dragonflies, horse guards (*Bembix* sp.), lizards, and spiders, all of which are frequently numerous around barns and corrals where livestock congregate. Numerous dragonflies are continuously on the wing around animals corralled near bodies of water. The author has observed dragonflies capture tabanids that escaped while he was making collections. The horse guard, *Bembix carolina* (Fab.), was observed to capture six tabanids from a horse in 15 minutes. An average of one to two per animal in a small herd has been observed. The lizard *Anolis carolinensis* Voigt, commonly called the chameleon, is a very abundant species around barns, corrals, and fences in some areas; it has been observed stalking and capturing the large species of horse flies. Numerous tabanids have been seen entangled in spider webs.

It is difficult to estimate the value of the predators in reducing the tabanid population in a given area, but they no doubt play an important part.

SUMMARY.—A study of the biology, distribution, and life cycles of the more abundant species of tabanids was undertaken in Florida in 1950.

There have been 108 species and subspecies of tabanids divided among 16 genera recorded for Florida, 66 of which were collected during this investigation.

Parasites or predators of all four stages of development were observed. Knowledge of their importance is incomplete, but they apparently play an important role in effecting natural control.

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Dosage of DDT Needed to Kill a House Fly[1,2]

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The work of Fisher (1952) provided the method utilized here for applying to the legs or labella of immobilized house fly adults, microgram quantities of DDT. Four-day old male flies of a strain reared at Macdonald College for the past 2 years were employed as test animals. The average mortality after 24 hours of 650 such test animals, each treated with two micrograms of DDT on the tibio-femoral joint of one metathoracic leg has been 68.5 per cent. Two procedures were used. (a) Flies were treated on legs or labella, the treated appendage amputated after an interval and mortality counts made after 24 hours. (b) Flies were treated on legs or labella with Carbon 14 labelled DDT, the treated appendages amputated after a period, the DDT or its metabolites extracted from the treated appendages and the remaining bodies, and the activity of the extracts determined to ascertain the amount which had penetrated and been distributed. The active DDT had been prepared by MacDonald (1953) from active sodium carbonate secured from Chalk River and has an activity of 2.24 millicuries per gram. Fifteen samples of two microgram quantities prepared as for fly treatment gave an average of

[1] This investigation was financed by a Fellowship of Canadian Industries Limited to the senior author and forms a part of a Ph.D. thesis to be submitted to McGill University in partial fulfillment of the requirements for a Ph.D. degree.

[2] Macdonald College Journal Series No. 325.

342±25 counts per minute on a continuous flow counter (geometry 2π) used. Counts were made from 5 to 10 minutes on all samples and activities corrected for background. In all instances the total counts from recovered DDT or metabolites indicated complete recovery of the applied dosage. Slight day to day differences in counter efficiency were not serious as all records are in terms of percentages of total recovered activity.

Groups of 15 or 20 flies were used to assure sufficient activity for accurate counting. The different parts of treated flies were dissected off at the desired interval, crushed, and extracted for 24 hours with two millilitres of benzol in small shell vials. Two aliquots of 0.5 ml. of extract were removed from each vial, evaporated to dryness in small steel sample cups at room temperature under slightly reduced pressure, counted, and the counts averaged. The inside edges of sample cups were lined with filter paper wet with distilled water to prevent external contamination of the cups from the benzol extraction creeping over the edge.

EXPERIMENTS AND RESULTS.—A. *Using Non-Active DDT.*—1. Fifty flies were treated with DDT (2 micrograms each) on the tibio-femoral joint. Their treated legs were amputated at the coxal joint 30 minutes later. After 24 hours 20 (40 per cent) of the treated flies were dead and three of 50 non-treated flies with legs similarly amputated were dead.

2. Fifty flies treated as in number one had their treated legs amputated after 4 hours. Fifty more were similarly treated but without amputation, and 50 had their legs amputated without treatment. After 24 hours 41 (82 per cent) of the treated amputated flies were dead; 42 (84 per cent) of the treated flies which had not had their legs amputated and 5 (10 per cent) of the check flies were dead.

3. One hundred flies were treated on the labella and those organs amputated after 30 minutes. After 24 hours 84 were dead, while only 14 of a similar number of amputated but nontreated check flies were dead.

B. *Using Carbon 14 Labelled DDT.*—1. Fifteen flies were treated on the tibio-femoral joint and sectioned after 30 minutes. Ninety-one per cent of the activity recovered was from the amputated leg.

2. Two groups of 15 flies each were treated on the tibio-femoral joint and sectioned after 4 hours. Eighty per cent of the activity was in the amputated leg.

3. Two groups of 20 flies each were treated on the labella and sectioned after 30 minutes. On one group 90 per cent and in the other 93 per cent of the activity was in the probscides.

SUMMARY.—Mortality of house fly adults treated with 2 micrograms of DDT was reduced by amputation of the treated leg after 30 minutes, but not after 4 hours. Amputation of treated labella after 30 minutes had no effect. Ninety-one per cent of the radio activity in an applied dosage of carbon 14 labelled DDT was recovered from treated legs and 90 per cent to 93 per cent from treated labella after 30 minutes, 80 per cent from treated legs after 4 hours. Absorption and distribution of 10 to 20 per cent of the applied dosage produced the full effect. The locus of application did not influence rate of absorption but did influence effectiveness.

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The Role of Virus Diseases in the Control of the Alfalfa Looper

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The alfalfa looper, *Autographa californica* (Speyer), at times has been responsible for serious damage to alfalfa and other crops in California. But during recent years, although widespread in occurrence, the population level generally has remained very low and thus the insect has been considered to be of little economic importance.

Two diseases, both viroses, have been reported from the alfalfa looper. Hyslop (1912) observed a larval disease of *Autographa californica* in the state of Washington. This disease, also known to occur in California and British Columbia, is considered to be a polyhedrosis virus by Steinhaus (1949). In May, 1952, diseased loopers were collected by Robert van den Bosch from an alfalfa field near Lancaster, California. According to Steinhaus (1952),[1] these larvae were infected by a granulosis virus.

Table 1.—Larvae of *Autographa californica* parasitized by polyhedrosis and granulosis viruses and other mortality-producing agents in several localities in southern California. Spring 1953.

Locality	Larvae Collected	Larvae Containing Mortality-Producing Agents			
		Polyhedrosis Virus	Granulosis Virus	Insect Parasites	Unknown Causes
Buena Park	4	1	3	0	0
Anaheim	3	1	2	0	0
Los Alamitos	3	3	0	0	0
Bakersfield	4	1	3	0	0
Chino	6	0	5	1	0
Chino	26	5	16	2	3

In the spring of 1953, work was undertaken to determine the presence of the above-mentioned diseases in the field and their effect on the looper populations. Loopers were collected from alfalfa fields in various sections of southern California.[2] The population levels in the fields sampled were found to be quite low, averaging 1 to 2 larvae per 10 sweeps with a University of California standard insect net. The larvae collected were brought to the laboratory at Riverside for observation and microscopic examination to determine the presence of disease organisms.

The data obtained from these collections and examinations are presented in table 1. Of four larvae, collected from an alfalfa field near Buena Park in

[1] E. A. Steinhaus, 1952. Unpublished data.

[2] The author wishes to acknowledge with thanks the assistance of E. J. Dietrick in making the field collections reported in this paper.

Orange County, one died of a polyhedrosis virus infection the following day and three died about 12 days later of a granulosis virus infection. Three larvae collected near Anaheim, also in Orange County, died after 4 days in the laboratory; one contained polyhedral bodies and two contained granules. Three larvae, collected near Los Alamitos in Los Angeles County, died of polyhedral infections within 4 days. Examination of four loopers collected near Bakersfield revealed that one dead larva contained polyhedra and two dead and one dying larvae contained granules. Six larvae were brought to the laboratory from a field near Chino in San Bernardino County. Five died of granulosis infection after 4 days. One contained a dipterous parasite.

Direct evidence of disease was noticed in another alfalfa field near Chino. Both dead and diseased larvae were collected by sweeping. Of 12 dead and dying loopers examined immediately upon return to the laboratory, five were infected with a polyhedrosis virus, three with a granulosis virus, two were parasitized by dipterous enemies and two were dead of unknown causes. Healthy-appearing larvae were reared in the laboratory for 4 days until they died. Thirteen of these larvae contained granules and one was dead of a bacterial infection.

It is not uncommon for diseases to appear in field-collected insects which are reared in the laboratory. Thus the appearance of polyhedrosis and granulosis viruses in the alfalfa loopers was not unexpected. Of interest is the presence of two virus diseases attacking low populations of the host in the same fields. In no instance were there signs of double infections with granules and polyhedra occurring in the same diseased insect.

The observation of the diseases in the alfalfa field near Chino gives an indication of the ability of the two diseases to effectively control the alfalfa looper under conditions of very low host density. The effectiveness of these two viruses in conjunction with the actions of certain insect enemies may explain why the alfalfa looper is rarely a serious pest.

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Value of Early-Season Control of Thrips on Cotton in the Santa Cruz Valley of Arizona

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Observations made over a number of years on cotton in Arizona showed there was a period of several weeks after the seedling plants had emerged from the ground when the plant growth was retarded. The factors most generally recognized as retarding seedling cotton growth have been climatic conditions, such as cool nights and high winds during the daytime, and certain plant diseases. Little attention had been given to the damage that thrips cause to the seedling plants, such as curled and irregular leaves, and to the terminal buds. It was generally thought that the injury was of minor importance and when weather conditions became favorable the plants would outgrow the damage and produce a full crop. The normally long growing season was thought to compensate for the period during which the seedling plants were retarded.

In 1949 an early frost occurred in areas south of Tucson and at elevations above 2,400 feet. This early frost (about the middle of October) in some cases caused losses estimated at 0.25 to 0.5 bale of cotton per acre. Since other investigators had reported that the early control of thrips caused the cotton to mature about 2 weeks earlier, experiments were started in 1950 to see if this would hold true under Arizona conditions and also to determine if yields would be increased with thrips control.

1950 EXPERIMENT.—This experiment was conducted in a field of approximately 60 acres near Continental, Ariz., planted to acala 44 cotton in mid-April. The field was slightly over 0.5 mile long, contained 326 rows of cotton, and was divided across the rows in the approximate middle by an irrigation ditch. Replicated plots were laid out and were so randomized as to have one early-treated plot, one untreated check plot, and one late-treated plot on each side of the ditch. Each plot contained approximately 10 acres of cotton. The experiment was so designed that, after the early treatment if insect populations warranted control measures, insecticides could be applied by airplane to both the early- and the late-treated plots in one continuous operation. The untreated plots, being continuous through the middle of the field, were not subjected to undue drift from airplane applications.

The first application was made with ground equipment when the plants were in the two- to four-leaf stage. A dust containing 5 per cent of DDT plus 75 per cent of sulfur was used at the rate of 10 pounds per acre, followed later in the season by three applications of a dust containing 10 per cent of DDT plus 75 per cent of sulfur used at the rate of 15 pounds per acre, principally for the control of the bollworm, *Heliothis armigera* (Hbn.).

1951 EXPERIMENT.—The same field was used as in 1950. The plot layout was also the same, with the exception that the early-treated plots were reversed. The first application was made with ground equlpment when the plants were in the two- to four-leaf stage, but not quite so advanced in growth as in 1950. A dust containing 10 per cent of toxaphene was used at the rate of 10 pounds per acre. This early treatment was followed by three late treatments with a dust containing 10 per cent of DDT plus inert material applied at the rate of 15 pounds per acre for the control of the beet armyworm, *Laphygma exigua* (Hbn.), and bollworms.

1952 EXPERIMENT.—The field used in 1952 was in the same locality and about the same size and arrangement as in 1950 and 1951, except that each of the early-treated plots was subdivided into two plots for treatment with different insecticides. Soon after the true leaves began to form two of these subplots were sprayed with 2 ounces of dieldrin emulsion in 2 gallons of water per acre and the other two with 1 pound of toxaphene in 2 gallons of water per acre. All applications were made with ground equipment. These early treatments were followed by two late treatments with a dust containing 20 per cent of toxaphene applied at the rate of 15 pounds for control of bollworms.

RESULTS.—Yield records and thrips counts made

Table 1.—Results of experiments conducted near Continental, Arizona, to determine the value of early-season thrips control on cotton.

Experimental Data	1 Early Plus 3 Late Treatments		1 Early Plus 2 Late Treatments
	1950	1951	1952
Average number of thrips per plant:			
Before 1 early application	5.5 (3.7)[1]	1.4 (1.5)	1.9 (1.3)
After 3 days	0.6 (4.0)	0.4 (2.9)	0.6 (3.1)
After 10 days	0.9 (15.8)	0.6 (3.6)	1.7 (5.8)
Average yield of seed cotton (pounds per acre):			
Early plus late treatments	2899	3034	2057
Late treatments only	2660	2612	1784
Check—No treatment	2414	2113	1710
Increase in yield (pounds per acre):			
Early plus late over check	485	921	347
Early plus late over late	239	422	273
Late over check	246	499	74

[1] Figures in parenthesis are the average number of thrips per plant in comparable untreated check plots.

in all plots during each year are summarized in table 1.

Each of the early treatments reduced the thrips population and held it far below the levels occuring in the untreated check plots for at least 10 days.

Plots receiving the early-season application of insecticide for thrips control plus two or three late applications showed increases in yield over plots receiving two or three late applications. The average increases of seed cotton per acre over comparable untreated check plots during the 3-year period were as follows: One early application only, 311 pounds; two or three late applications only, 273 pounds; one early application followed by two or three late applications, 584 pounds.

Thysanus flavopalliatus (Ashm.) Parasitic on *Comperiella bifasciata* How. in California Red Scale

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Adult specimens of *Thysanus flavopalliatus* (Ashm.)[1] were collected in November, 1952 in the field near Escondido, California, on lemon fruits heavily infested with the California red scale, *Aonidiella aurantii* (Mask.). Laboratory dissection yielded mature larvae and pupae of *Thysanus* in mummified red scales and later adults emerged. This is the only known record of *Thysanus* from *A. aurantii* in recent years and may be the first authentic record of *Thysanus* being reared from the California red scale. Although Muesebeck, Krombein and Townes (1951) list *T. flavopalliatus* and *T. occidentalis* as having been reared from *Aonidiella aurantii* these records are questionable. The information on *T. occidentalis* apparently is based on L. O. Howard's records of material collected in 1887 at San Gabriel, California. It is clear from Howard's (1894) account that the San Gabriel scale was yellow scale, *Aonidiella citrina* (Coq.), and not California red scale. In addition, other parasites which attack yellow scale but not California red scale were present on Howard's *Thysanus occidentalis* slides. The information on *T. flavopalliatus* apparently is based on Girault's (1913, p. 199–200) discussion. Girault included *T. occidentalis* under *T. flavopalliatus* and it appears that Muesebeck *et al.* used the *T. occidentalis* host records as applying to *T. flavopalliatus*. Thus the previous discussion again applies.

Inasmuch as *Comperiella bifasciata* How. (Chinese strain) was also present in the red scale infestation as an internal parasite, it was unknown whether the *Thysanus* were issuing as primary or secondary parasites. The few published biological studies on *Thysanus* species have shown only hyperparasitic development. However, previous work (unpublished notes), by the author, Roy J. Pence (University of California at Los Angeles) and Charles Kennett (University of California at Albany) has shown species of *Thysanus* to be common primary parasites of both latania scale on avocados and greedy scale on citrus and other host plants. Accordingly, tests were run to determine whether *Thysanus flavopalliatus* developed as a primary or secondary parasite.

Thysanus flavopalliatus adults which emerged from the field-collected material were put with laboratory reared California red scale containing *Comperiella* larvae and pupae as well as with unparasitized red scale. *Thysanus* larvae were dissected from California red scale as external parasites on *Comperiella* pupae. Adult *Thysanus* emerged after 31 days at 75° to 80° F. No evidence of parasitism was found in the pure culture of red scale subjected to *Thysanus*.

[1] This species is very similar to *T. occidentalis* (Howard). According to Girault (1913) they are synonomous. The specimens do not agree completely with the original descriptions of either species. Specimens on slide mounts are on file in the collection of the Department of Biological Control, Riverside.

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Mite Injury to Sorghum in the Lower Rio Grande Valley of Texas

R. D. GRIFFITH[1] AND GEORGE P. WENE[2]

A mite, *Paratetranychus pratensis* (Banks), was found on June 8, 1953, injuring sorghum in the vicinity of San Manuel, Texas. A survey showed that this mite was distributed throughout the entire Lower Rio Grande Valley. Although the mite was present in irrigated fields, injury was confined to those fields grown in the dry lands.

Feeding by this mite caused the leaves to dry up prematurely. In some fields these mites killed the plants before the seed heads had developed, which rsulted in a crop failure. The type of damage is il-

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lustrated in figure 1. In many fields most of the leaves had been killed which resulted in a yield reduction. Heavy mite infestations can be detected

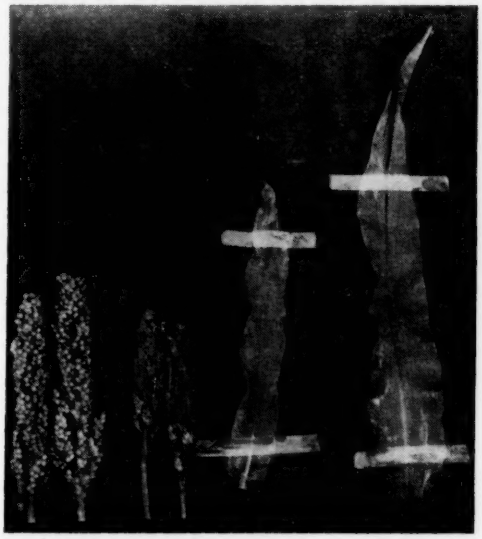

FIG. 1.—Two sorghum heads at left from field with low mite population; other heads from an adjacent field of the same age but with a heavy mite infestation. Small leaf is from the heavily infested field; the large leaf is from the lightly infested field.

easily by the webs which collect dirt. These are usually on the underside of the leaves or on the sorghum heads. The prevailing winds are from the southeast and it is interesting to note that the heaviest concentrations of webs are located on the northwest side of the head or plant. As many as 130 mites per square inch of sorghum leaf area were found. Mite infestations apparently start developing on the underside of the lower leaves and become concentrated along the midrib, usually under a very delicate web. The area along the midrib loses its color, and as the population increases the web becomes much heavier covering most of the leaf collecting dirt from the prevailing winds. As the population becomes denser on the lower leaves, and as the leaves dry up the mites migrate to other leaves on the plant.

A 6-acre section of a heavily infested field was dusted with 1 per cent parathion at the rate of 15 pounds per acre. An area 1 acre in size was used as a check area. On the other side of the untreated area a 3-acre plot was dusted with sulphur at the rate of 35 pounds per acre. The insecticides were applied with a tractor-drawn duster. Two days later 30 leaves were pulled at random from the lower parts of the plants and the surviving mites on the underside of the leaves were counted. The sulphur-dusted plot average 0.3 mites per square inch; the parathion-dusted plot 34.2 mites per square inch; and the untreated area averaged 28.9 mite per square inch. The data indicate that sulphur may be used to control the mite when found in injurious numbers on sorghum.

Toxicity of Various Fumigants to Sweetpotato Weevils and Their Effect on Sweetpotatoes

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Methyl bromide has been used extensively for several years for fumigating sweetpotatoes that are to be moved from infested to noninfested areas in the Southern States. Approximately 800,000 bushels are fumigated annually in southwestern Louisiana alone. The treatment consists of a 4-hour fumigation at a dosage of 3.5 pounds per 1,000 cubic feet, with a minimum pulp temperature of 70° F. Although giving weevil control, it has two objectionable features: (1) Uncured potatoes or those that have been injured by cold or adverse growing or storage conditions may be rather severely injured; (2) it is often difficult to increase pulp temperature to the desired 70° during the winter season. At temperatures below 70° weevils are much more difficult to kill and potatoes become less tolerant to the treatment.

To determine whether some other fumigant could

Table 1.—Toxicity of various fumigants to the sweetpotato weevil and their effect on sweetpotatoes as compared with methyl bromide.

Fumigant[1]	Dosage, Lbs. per 1,000 Cu. Ft.	Exposure, Hours	Per Cent		
			Mortality	Sweetpotatoes Injured	
				Slightly	Seriously
Methyl bromide	3.5	4	100	8	0
Ethylene chlorobromide	5.0	24	76	0	0
Ethylene dibromide	5.5	4	33	20	0
Propylene oxide	19.0	24	100	0	100
Ethylene dibromide 20.4% plus ethylene dichloride 19.6% and carbon tetrachloride 60%	21.0	8	100	5	5
Carbon bisulfide 16.5% plus carbon tetrachloride 83.5%	36.0	8	100	25	0
Ethylene dichloride 70.2% plus carbon tetrachloride 29.8%	42.0	8	100	0	100

[1] The individual fumigants were technical-grade products and the composition of the mixtures is indicated in per cent by weight.

be used to replace methyl bromide, a series of tests were run with several promising formulations. All fumigations were made under atmospheric pressure. Most of the fumigants were tested in an 8-cubic-foot metal drum having a metal cover provided with rubber gaskets that formed a tight seal. Ethylene chlorobromide was tested in a 100-cubic-foot metal-lined chamber equipped with a blower, as the smaller chamber did not contain an air-circulation unit. The fumigants were either volatilized on a pan or vaporized by heat near the top of the chamber, and the sample sweetpotatoes were suspended 8 inches above the bottom of the chamber.

Many tests were run to determine the most effective dosage and exposure. The results of the most effective treatments are given in Table 1.

Methyl bromide is shown to be better suited for treating sweetpotatoes than any of the other fumigants. At the lethal dosage level it caused less injury to the sweetpotatoes and its action was faster. Slow-acting fumigants would not be particularly objectionable for use in the treatment of seed stock, but would be impractical for treating sweetpotatoes involved in commercial movement.

Further Notes on *Hypera brunneipennis* and Its Parasite, *Bathyplectes curculionis*

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Field observations made in 1952 showed the Egyptian alfalfa weevil, *Hypera brunneipennis*, (Boh.) to be extensively parasitized by the ichneumonid *Bathyplectes curculionis* (Thoms.) in coastal San Diego County, California, but not at all in the Imperial Valley (van den Bosch 1953). Because of this condition a decision was made to attempt introduction of the parasite from the coastal area into the Imperial Valley despite the reported failure of an earlier effort to effect its establishment in the desert area at Yuma, Arizona (McDuffie 1945).

During 1953 release plots were established at the Meloland field station of the University of California and at the R. O. Smith Ranch near Brawley. Adult parasites and parasitized weevil larvae collected in San Diego County were released in the plots during February and March, an estimated 1200 parasites being released at each place. A small number of weevil larvae swept from the Meloland plot at the end of the season (May 1) produced *Bathyplectes* cocoons indicating establishment of the parasite at that locality. No *Bathyplectes* were recovered from the Brawley plot during the season. Permanent establishment of *Bathyplectes* at Meloland should be effected if the parasites can survive the long aestivation period (May to December) and resume their attack on the weevil larvae in 1954.

Except for the Meloland release plot, no *Bathyplectes* were recovered from a large number of weevil collections made in the Imperial Valley in 1953, as was the case in 1952. Survey in the coastal area revealed the parasite to be much more widely distributed in San Diego County than in 1952, but not yet established on new weevil infestations in Orange and Los Angeles counties. However, one of four weevil larvae collected at Riverside was parasitized.

A development of particular interest and significance occurred in April when *Bathyplectes* was reared from a collection of weevil larvae swept from alfalfa at Bard on the Arizona border. In this collection of 75 specimens, 19 *Bathyplectes* were recovered (parasitization of 25.3 per cent). Because of the lateness of the season (weevils had practically disappeared from the field) a survey to determine the distribution of the parasite in the area was not possible. However, the data obtained indicate that *Bathyplectes* is well established at Bard. Since Bard is located directly across the Colorado River from Yuma there can be little doubt that the *Bathyplectes* occurring there must have spread from colonies which became established from the releases made by the U. S. Department of Agriculture in 1941 (McDuffie 1945). A thorough survey of the Bard-Yuma area for *Bathyplectes* is planned for 1954.

The presence of *Bathyplectes* at Bard offers a possible explanation for the lack of damage by *Hypera brunneipennis* in that area since the parasite may be keeping it from developing to injurious abundance. It also appears to explain the presence of *Bathyplectes* in San Diego County as it was probably transported directly to the coast on baled alfalfa hay delivered to San Diego dairies. The presence of *Bathyplectes* at Bard is especially significant because it shows that the parasite is able to survive the extreme desert heat and should thus be able to develop successfully in the Imperial Valley. Since *H. brunneipennis* is of marginal economic status in the Imperial Valley even a relatively low degree of parasitization may prove sufficient to reduce it below the economic threshold. It is planned to introduce parasites from the Bard Valley into the Imperial Valley in 1954.

In March of 1953, the junior author had the opportunity to observe and collect *Hypera brunneipennis* in Egypt where the weevil was encountered on Berseem clover, *Trifolium alexandrinum*, at Giza. It was quite readily swept from several fields in which feeding injury was conspicuous but not damaging to the stands of clover. One Egyptian entomologist observed that these infestations were much heavier than normal. Several weevil shipments were sent to the quarantine laboratory at Riverside, in the hope that parasites might be recovered. These collections yielded no parasites nor were any adults (*Bathyplectes*) observed in the field in Egypt. Because of the abundance of the weevil and the lack of parasites there is reason to doubt that Northern Egypt is its native habitat.

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Another Wireworm of Irish Potatoes[1]

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A study of wireworms conducted in the vicinity of Hastings, Florida, between March, 1952 and May, 1953 indicates that the chief species injurious to potatoes in this area is *Conoderus vagus* Candèze. This insect was identified by Mr. M. C. Lane of the Bureau of Entomology and Plant Quarantine, Walla Walla, Washington, from specimens sent to him from Hastings.

The literature on economic wireworms does not contain any reference to this species. A note referring to the present author's collections of this species in the Hastings area was reported in the Cooperative Economic Insect Report (Lane 1953). The note appeared under "Truck Crop Insects," but did not speak of this species as a pest of any specific crop. This is the first report, therefore, that this wireworm is a pest of Irish potatoes, or the first reference to it as an economic insect injurious to a particular crop.

The original description of this insect was made from specimens from Buenos Aires, Argentina in 1893 (Candèze 1893). The earliest record of its occurrence in the United States is from Chadbourn, N. C., where some specimens were collected in 1927. In 1929, Fall, apparently unaware of the previous work, redescribed it as *Monocrepidius difformis* (Fall 1929). According to Lane's note, its present distribution in the United States is along the coasts of North Carolina, South Carolina, Georgia, Northern Florida, Mississippi, and Alabama. In personal correspondence, Lane indicates that its occurrence in Florida is not restricted to the Hastings area, that it has been collected also at Tampa and Winter Park and that the time and manner of its introduction into the United States are not known.

When this wireworm was found in potato fields near Hastings, the question arose as to whether or not its presence had any relation to the wireworm injuries occurring in those fields. The following information is presented as evidence that the wireworm *Conoderus vagus* Candèze is a pest of Irish potatoes, and that it is the chief economic wireworm infesting potato fields of the Hastings area.

1. With few exceptions, the adult Elaterids collected during the past 12 months in the immediate vicinity of Hastings were *C. vagus*.

2. From 44 larvae collected in potato fields, 36 adults were reared, all of which proved to be *C. vagus*.

3. All of the above larvae kept in the laboratory fed on potatoes freely and often voraciously.

4. More than 100 wireworms, hatched in the laboratory from eggs laid by beetles of this species, were given potatoes. Although potatoes alone did not furnish an adequate diet on which to complete development, all of these larvae fed on potatoes.

5. Seven full-grown wireworms were taken from their burrows in potato tubers as a digging machine brought the infested tubers to the soil surface. Five of the larvae completed their development on potatoes in the laboratory, and all were identified as *C. vagus*.

On the basis of the above evidence, the larva of *Conoderus vagus* Candèze should be added to the list of wireworms injurious to Irish potatoes.

[1] Florida Agricultural Experiment Station Journal Series, No. 188.

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The Elongate Flea Beetle as a Pest of Peanuts[1]

W. H. LONG and J. R. DOGGER[2]

During the past decade considerable research effort has been directed toward the control of subterranean insects injurious to developing peanut pods. This research has shown that in the peanut growing areas of southeastern Virginia and northeastern North Carolina the southern corn rootworm, *Diabrotica undecimpunctata howardi* Barber, is one of the most important of these subterranean pests. In North Carolina it is believed that the rootworm is generally responsible for more insect injury to peanuts than any other insect.

It has recently come to the attention of the authors that some of the pod injury, attributed to the southern corn rootworm in the past, may be caused by other insects. The purpose of this paper is to call attention to another insect, the elongate flea beetle, *Systena elongata* (F.), the larval ravages of which have not heretofore been reported on peanuts.

DISTRIBUTION.—This insect is found throughout the state and the adults are active from February through November. They are most abundant, however, in the eastern Coastal Plains which includes North Carolina's most productive peanut producing area.

LITERATURE.—There is comparatively little economic literature concerning *Systena elongata*. Underhill (1928) reports on the life history and control of the pale-striped and banded flea beetles, which he refers to as *Systena blanda* and *Systena taeniata* respectively. It was the opinion of Bissell (1941) that the insect referred to by Underhill as *S. taeniata* is correctly known as *S. elongata*, commonly known as the elongate flea beetle. The authors are of the same opinion on this point. Underhill reports two generations annually for Virginia with the peak of oviposition occurring in May for the first generation, and in late July and early August for the second generation. He found an average incubation period for the second brood eggs of just a fraction over 15 days. Underhill's list of host plants includes peanuts, but evidently refers only to the adult beetles, as he writes that the larvae of the flea beetles feed on the roots of weeds and cause no noticeable injury to crops. Bissell (1941) collected the beetle consistently for over 10 years in Georgia in every month except January. He also reports collecting the adult on peanuts. Marcovitch & Stanley (1945) report injury to sweet potatoes by *Systena* larvae in Tennessee. The same authors (1946) point to this flea

[1] Contribution from the Entomology Department. Published with the approval of the Director as paper no. 519 of the Journal Series.

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beetle larva as the principle insect responsible for pinholes and pits often found on sweet potatoes. As far as the authors know this is the only previous report of economic injury to crop plants by *Systena elongata* larvae.

FIELD OBSERVATIONS.—Injury to peanuts by *Systena* larvae was first noticed by the writers on July 31, 1953, on the Peanut Experiment Farm at Lewiston, N.C. During the summer of 1953, a program was set up for measuring seasonal fluctuations in population levels of insects injurious to peanuts. As part of this program, soil examinations were made at the peanut farm at approximately 10-day intervals. At each examination an ordinary spading fork was employed in turning and examining samples of a single foot of row from each of 36 plots which had not been treated for southern corn rootworm control. Each foot sample reached to the middle on either side of the peanut row, the rows being spaced 2 feet apart, and was approximately 8 to 10 inches deep. The soil was examined by hand on the spot, and all pods showing possible injury were opened in an attempt to find any insects that might have been feeding within. The numbers of immature *S. elongata* found in the samples in all 36 plots on the various sampling dates are tabulated below:

DATE	NUMBER OF	
	Larvae	Pupae
July 30, 31	1	0
August 7, 8	16	3
August 18, 19	30	3
August 26, 27[3]	9.5	1.5
September 7, 8	1	5
September 17, 18	0	1

It seems probable that the peak of oviposition might well have been reached near mid-July. Adults were observed to be quite common in peanut fields during the last 3 weeks of July. Allowing 2 weeks for incubation, the majority of larvae should be active in the soil by the first half of August. By reference to the tabulation it is seen that this is approximately what happened. By late August the number of larvae had decreased, and by early September most of the immature *Systena* were apparently in the pupal stage. No careful field counts were made of the adult beetles. However, the first adult beetles of the new generation were noticed in the field on August 18, and their numbers appeared to increase steadily until they were very numerous on September 17.

LABORATORY OBSERVATIONS.—Eighteen beetles emerged in the laboratory from August 21 to September 16, 1953. These were reared from larvae and pupae collected in the field from August 8 to September 7, 1953, and kept in 2.5-inch salve boxes half filled with the soil in which they were found. The beetles were identified by Mr. D. M. Weismann of N. C. State College.

DESCRIPTION OF INJURY.—The injury caused by larvae of the elongate flea beetle is very similar to that caused by the southern corn rootworm with which it was closely associated during the summer of 1953. The larvae bore through the shell and into the pods, seeming to prefer the younger, immature pods. Injury to more nearly mature pods also occurs although these pods usually show pits and scars denoting attempted entrance. After penetrating the shell the insect tunnels and feeds in the soft, succulent, inner tissues of the pod and in the developing kernels themselves. In cases where insect tunneling has not resulted in complete economic loss of the pod by the insect, the entrance holes afford easy entrance for decay organisms which quickly render the pod worthless.

[3] Two samples per plot were taken at this time and figures represent average numbers.

Table 1.—Insect injury to peanut pods at the Peanut Experiment Farm, Lewiston, N. C. 1953.

DATE	NO. PLANTS EXAMINED	AV. NO. OF PODS PER PLANT	PER CENT OF PODS INJURED BY		TOTAL PODS INJURED (PER CENT)
			Diabrotica	*Systena*	
Aug. 7, 8	42	38.3	1.9	2.3	5.1
Aug. 18, 19	50	47.7	1.9	4.8	7.0
Aug. 26, 27	106	47.3	7.9	3.3	12.7

IMPORTANCE OF INJURY.—Due to the difficulty of distinguishing between injury by the southern corn rootworm and the elongate flea beetle where they occur together, it was necessary to calculate the damage done by each on the basis of the ratio of their populations in any particular sample. If a sample showed injury of this type, but contained neither of these insects, the calculation was made on the basis of the total field population of the two insects. Some injury by the southern corn rootworm was observed throughout the summer, commencing with the formation of the first pods and continuing until harvest. Most of the rootworm injury was done during August and September, while the ravages of the flea beetle larvae were mostly confined to the month of August. Table 1 shows the estimated amount of injury done by each of these insects together with the total amount of insect injury occurring during the month of August, 1953.

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Effect of Certain Systemic Compounds on Southern Red Mite Infesting Camellias

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The southern red mite, *Paratetranychus ilicis* (McG.), is a major pest of camellias and azaleas in Alabama. English and Turnipseed (1940) reported the mites feeding on both leaf surfaces, rasping the epidermis, withdrawing plant juices, and causing the leaves to become reddish brown on their upper

[1] The writers acknowledge the cooperation of Dr. R. L. Self, Superintendent of the Ornamental Horticulture Field Station.

surfaces. Severe infestations discolored all of the leaves and caused some of them to drop. This damage resulted in decreased plant vigor and a decrease in sale value of plants.

The southern red mite can be controlled in cool weather with white oil sprays on small camellia plants where all leaf surfaces are sprayed. On large plants with dense foliage mite control is difficult. The need for more satisfactory acaricides has prompted a study of the effect of systemic compounds on the southern red mite attacking camellias. Results of preliminary experiments are reported herein.

MATERIALS AND METHODS.—Greenhouse experiments were conducted at the Ornamental Horticulture Field Station, Spring Hill, Alabama, to determine the LD-50 and LD-90 concentrations of schradan,[2] Systox,[3] and 21/116[4] applied to the soil for control of southern red mite on camellias. The plants used in the experiments were camellia liners of the Gloria de Nantes variety. The liners were planted in metal pots containing soil that was uniform in amount and texture. The surface area of the soil was calculated and the systemics were applied at various rates per acre.

Southern red mites were introduced to the liners by placing the pots in close proximity to heavily infested plants approximately 2 months before the soil was treated. The liners were protected from rainfall with glass sashes to prevent the dislodging of the mites. Before treatment, the plants were moved into the greenhouse and were arranged in a randomized block design in five replications.

The soil in the pots was treated with the compounds as emulsifiable concentrates in 40 ml. of water. There was no run-off of the emulsion through the porous soil or from the pots. The plants were treated only once in each experiment.

Random counts were made of living and dead mites on the plants before treatment. Additional infestation counts were made at weekly intervals for 4 weeks following the soil treatment. Counts were made of mites on 1 square inch of the lower surface of two leaves on each plant. Both live and dead specimens were counted. However, only living mites were used in calculating effectiveness. Many dead mites dropped off the leaves and could not be found.

RESULTS AND DISCUSSION.—Systox and its analog, compound 21/116, were highly effective against southern red mite (Table 1). At the higher dosage levels, both materials killed more than 90 per cent of the mites 1 week after application to the soil and remained effective throughout the 4 weeks of the experiment. Compound 21/116 was more efficient than Systox. Schradan was slow in its systemic action and gave erratic results throughout the test. Low doses in the soil frequently resulted in greater mortality of mites than higher doses. Best results from schradan were at the end of 4 weeks after application. There was no visible phytotoxicity from any compound at any concentration.

LD-50's calculated from dosage-mortality curves revealed LD-50's of 0.6 and 2.2 pounds per acre for compound 21/116 and Systox, respectively, under the conditions of the experiment. It was not possible to calculate LD-50's from the schradan-treated plants. The LD-90 for compound 21/116 was 4.8 and for Systox was 9.5 pounds per acre.

Effective doses of all three materials were probably too high for economical control. Compound 21/116 at the rate of 3 pounds per acre gave 97 per cent control at the end of 4 weeks and averaged 88 per cent over the 4-week period. A dosage of 5 pounds of technical Systox per acre was required for 92 per cent control at the end of the test and 73 per cent over the entire period. Although schradan was fairly effective at the end of 4 weeks, there was little relationship between amount applied to the soil in this experiment and percentage of mite mortality.

Table 1.—Mortality of southern red mite on camellias after application of systemic compounds to the soil, five replications, 1953.

Treatment January[1]	Pounds per Acre	Average Per Cent Kill[1] Following Treatment				
		Jan. 18	Jan. 25	Feb. 1	Feb. 8	Average
Check	0	—	—	—	—	—
Schradan	12	11.3	66.9	40.2	87.7	51.5
Schradan	10	18.9	51.7	61.0	79.4	52.8
Schradan	8	8.5	71.2	64.9	72.6	54.3
Schradan	6	37.7	66.1	71.4	91.8	66.8
Schradan	4	72.6	60.2	63.6	93.1	72.4
Schradan	2	50.0	73.7	83.1	80.5	71.8
Systox	11	86.8	88.1	96.1	94.5	91.4
Systox	9	92.4	84.7	90.9	100.0	92.0
Systox	7	86.8	94.1	87.0	80.8	87.2
Systox	5	79.2	68.6	53.2	91.8	73.2
Systox	3	21.7	72.0	35.1	86.3	53.8
Systox	1	20.7	51.7	9.1	75.3	39.2
21/116[2]	11	97.2	99.1	100.0	98.6	98.7
21/116	9	91.5	91.5	98.7	100.0	95.4
21/116	7	92.4	92.4	90.9	98.6	93.6
21/116	5	86.8	89.8	93.5	97.2	91.8
21/116	3	76.4	87.3	89.6	97.2	87.6
21/116	1	53.8	71.2	53.2	80.8	64.8

[1] Calculated by formula of Abbott (1925).
[2] Analog of Systox.

The cool weather during January and February was doubtless a factor in the high dosages required to kill the mites. In addition, larger amounts are required in the soil than on the foliage. Experiments with foliage applications are in progress.

SUMMARY.—Replicated experiments were conducted in the greenhouse during January and February, 1953, on the effect of schradan, Systox, and compound 21/116 (analog of Systox) applied to the soil on mortality of southern red mite, *Paratetranychus ilicis* (McG.), infesting camellia liners. LD-50's, calculated from dosage-mortality curves, were 0.6 pound compound 21/116 per acre and 2.2 pounds Systox. Both materials were still effective 4 weeks after application. LD-90's were 4.8 for 21/116 and 9.5 for Systox. Schradan was slow in its systemic action and gave results too erratic to permit the calculation of LD-50. Best results with schradan were 4 weeks after it was applied to the soil.

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[2] Octamethyl pyrophosphoramide.
[3] O-[2-(ethylmercapto)ethyl]0,0-diethyl thiophosphate.
[4] An analog of Systox, 0-[2-(ethylmercapto)ethyl]0,0-dimethyl thiophosphate, that has been reported relatively non-toxic to warm-blooded animals.

Control of Mosquito Larvae and Pupae with Some Chlorinated Hydrocarbons

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For more than a quarter of a century an annual campaign has been carried on in Winnipeg and vicinity, Manitoba, to control mosquitoes. In recent years DDT has been used to control the larvae and adults. Mitchener (1953) showed that aldrin, dieldrin, endrin and isodrin gave excellent larval control at the rate of one part of actual insecticide to one million parts of water. DDT gave good control at the same concentration. When these same insecticides were used at the same concentration on pupae, endrin gave excellent control and aldrin, dieldrin and isodrin fair control, but DDT gave very poor control. Experiments were continued in 1953 using weaker concentrations of the same insecticides. Toxaphene was also included among the chemicals used in 1953.

MATERIALS.—Mosquitoes were unusually abundant in Winnipeg during the summer of 1953 due to an abnormally heavy summer rainfall. Larvae were taken in quantity from heavily infested water on two occasions for the experiments recorded in this paper. The first collection of approximately 2-day old larvae was made on May 22. These were kept at approximately 75° F. and fed regularly on powdered kibbled dog food. Pupation had begun by May 31. First adults emerged on June 2. The second larval collection was made on June 8. The pupae used in these experiments were reared from these two larval collections. Two species of mosquitoes only occurred in each collection. Out of 52 adults reared from these two collections and identified, 28 were *Aedes dorsalis* (Mg.) and 24 were *Aedes vexans* (Mg.). McLintock (1944) showed that these two species were perhaps the most abundant species occurring in the Winnipeg area in 1938 and 1939.

METHODS.—All experiments were carried out in 2000 cc. beakers at a room temperature averaging approximately 75° F. Twenty-five larvae or pupae were placed in 1000 cc. distilled water in each of seven beakers including the check. Each chemical used was in the form of an emulsifiable concentrate. A stock solution of each insecticide was made to contain one part of actual toxicant to 1000 parts distilled water by weight. The appropriate amount of the stock solution was then introduced into each beaker with a one cc. pipette for the successive trials.

Table 1.—Effects of insecticides at a dilution of one part per million parts of distilled water on mosquito larvae.

Insecticide	Number Used	24 Hours After Treatment: Number Dead	Number Alive	Per Cent Dead
Aldrin	49	49	0	100
DDT	49	49	0	100
Dieldrin	50	50	0	100
Endrin	50	50	0	100
Isodrin	48	48	0	100
Toxaphene	49	47	2	96
Check	50	0	50	0

RESULTS.—The results of these experiments are shown in tables 1 to 6.

DISCUSSION.—Table 1 shows that at one p.p.m. on larvae, aldrin, DDT, dieldrin, endrin and isodrin gave complete control and toxaphene satisfactory control. At one part of actual toxicant per two million parts of distilled water table 2 shows that aldrin, DDT, dieldrin, endrin and isodrin gave satisfactory control while toxaphene was slightly less toxic. Table 3 shows that the insecticides were similarly effective at one part of each toxicant to five million parts of water. Table 4 shows that at one part toxicant to ten million parts of water aldrin, DDT, dieldrin and endrin gave very satisfactory control while isodrin and toxaphene were much less toxic.

Mitchener (1953) showed that at one p.p.m. on mosquito pupae, endrin gave excellent control. Table 5 shows that on pupae at one part toxicant to two million parts of water, endrin again gave excellent control with dieldrin and isodrin following in that order. None of the insecticides gave satisfactory control at one part toxicant to five million parts of water as shown in table 6 although these same three insecticides were the most toxic. It is apparent that pupae are definitely more resistant to the insecticides used in these experiments than are the larvae. Endrin evidently is very promising against mosquito pupae as well as an excellent larvicide.

Table 2.—Effects of insecticides at a dilution of one part per two million parts of distilled water on mosquito larvae.

Insecticide	Number Used	24 Hours After Treatment: Number Dead	Number Alive[1]	Per Cent Dead
Aldrin	99	96	3	96.9
DDT	99	96	3	96.9
Dieldrin	100	97	3	96.9
Endrin	100	99	1	98.9
Isodrin	101	99	2	98.0
Toxaphene	100	93	7	92.9
Check	149	2	147	1.3

[1] Includes live pupae counted as larvae, except in untreated check.

Table 3.—Effects of insecticides at a dilution of one part per five million parts of distilled water on mosquito larvae.

Insecticide	Number Used	24 Hours After Treatment: Number Dead	Number Alive	Per Cent Dead
Aldrin	101	100	1[1]	99.0
DDT	100	100	0	100.0
Dieldrin	101	100	1	99.0
Endrin	101	99	2	98.0
Isodrin	99	96	3[1]	96.9
Toxaphene	103	94	9[1]	91.1
Check	150	2	148	1.3

[1] Includes live pupae counted as larvae.

Table 4.—Effects of insecticides at a dilution of one part per ten million parts of distilled water on mosquito larvae.[1]

Insecticide	24 Hours After Treatment		
	Number Dead	Number Alive[2]	Per Cent Dead
Aldrin	95	5	95.0
DDT	98	2	98.0
Dieldrin	95	5	95.0
Endrin	98	2	98.0
Isodrin	81	19	81.0
Toxaphene	84	16	84.0
Check	0	100	0.0

[1] Used 100 larvae in each test.
[2] Larvae alive showed only slight movement and would not likely recover. (Except DDT and Check).

In calculating the percentage of larvae or pupae killed in each table the formula (Abbot 1925) was used.

SUMMARY AND CONCLUSIONS.—Aldrin, DDT, dieldrin, endrin, isodrin and toxaphene are all satisfactory larvicides on *Aedes dorsalis* (Mg.) and *Aedes vexans* (Mg.) at one part per million parts of water.

Table 5.—Effects of insecticides at a dilution of one part per two million parts of distilled water on mosquito pupae.

Insecticide	Number Used	24 Hours After Treatment		
		Number Dead	Number Alive[1]	Per Cent Dead
Aldrin	89	27	62	30.4
DDT	90	27	63	30.0
Dieldrin	90	70	20	77.8
Endrin	90	89	1	98.9
Isodrin	91	64	27	70.4
Toxaphene	89	2	87	2.3
Check	89	0	89	0.0

[1] Includes adults which had emerged, except for endrin.

Table 6.—Effects of insecticides at a dilution of one part per five million parts of distilled water on mosquito pupae.

Insecticide	Number Used	24 Hours After Treatment		
		Number Dead	Number Alive[1]	Per Cent Dead
Aldrin	75	27	48	34.2
DDT	75	8	67	8.2
Dieldrin	75	48	27	63.0
Endrin	74	46	28	61.1
Isodrin	74	44	30	58.3
Toxaphene	74	4	71	2.7
Check	75	2	73	2.7

[1] Includes adults which had emerged, except for dieldrin and endrin.

At one part to two million and five million parts of water respectively good control was obtained with aldrin, DDT, dieldrin, endrin and isodrin while toxaphene was less toxic. Even at one part to ten million parts of water aldrin, DDT, dieldrin and endrin gave good control.

Endrin gave excellent control of pupae at one part to two million parts of water. Dieldrin and isodrin came next in that order. There was little difference among these three insecticides at one part to five million parts of water.

ACKNOWLEDGMENTS.—The author gratefully acknowledges financial assistance from Shell Oil Co. of Canada, Ltd., Toronto, Ontario, and from Hercules Powder Co., Inc., Wilmington, Delaware, in carrying out this undertaking. I wish also to acknowledge the assistance of Mr. B. Furgala, graduate assistant and Mr. T. H. Smith, student assistant who did much of the routine work. Mr. E. J. Stansfield, Field Manager of The Greater Winnipeg Anti-mosquito Campaign located the sources of larvae. Thanks are also due to Mr. G. E. Shewal, Systematic Entomology, Division of Entomology, Department of Agriculture, Ottawa for identifying the adult mosquitoes reared from the two larval collections.

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Control of Tipulidae Larvae (*Tipula cunctans* Say)

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There are relatively few references to craneflies in the literature of economic entomology. Packard & Thompson (1921) reported on the biology and control of the range craneflies in California; viz., *Tipula simplex* Doane and *T. quaylii* Doane which were damaging California ranges, pastures, grains, and alfalfa during certain rainy seasons. Maggots often numbered as many as 300 per square foot and they reported 72 per cent control with Paris green-bran bait. Gilmore & Milan (1934) reported on a new pest on tobacco plant beds, *Limnobia ultima* O. S. Effective control was obtained by drenching the beds with a solution of potassium permanganate and nicotine sulphate. Hyslop (1910) reported on an infestation of the smoky cranefly, *Tipula infuscata* Loew., occurring in Madison County, Tennessee, doing extensive damage to *Lespedeza striata*. Hyslop's paper describes and illustrates the various life stages and gives pertinent data on the life history of this Tipulid, the taxonomic position of which was later re-established as *Tipula cunctans* Say (Alexander 1920).

A heavy infestation of *Tipula cunctans*[1] larvae occurred in Graves County, Kentucky, in the early spring of 1953. General infestations occurred in old lespedeza fields or in some fields where spring oats were seeded in these lespedeza fields. The organic matter from the previous season formed a thin

[1] Identified by Dr. Alan Stone.

rotting mat on the surface of the ground and although the larvae were apparently feeding on this material, the germinating lespedeza or oats were being virtually destroyed by the tunneling and churning of the top two inches of the soil surface (Fig. 1). Examination showed that direct feeding on the germinating lespedeza was also occurring; it was difficult to ascertain which factor was most responsible for the destruction.

FIG. 1.—Tunneling of *Tipula cunctans* on the top two inches of soil. A dime indicates relative size of larvae and tunnels.

A small test plot was established in an old lespedeza field of 7 acres in size and uniformly infested; counts of 85 to 100 larvae per square foot were common and these occurred in the top 2 inches of the soil surface. Plots 0.01 acre in size were treated on March 27 using a compressed air sprayer equipped with a flat pattern *Teejet* nozzle and using 50 gallons of spray mixture per acre. The results of this test are presented in table 1.

Table 1.—Control of *Tipula cunctans* Say infesting germinating lespedeza. Mayfield, Kentucky.

TREATMENT AND DOSAGE PER ACRE	TOTAL LARVAE EXAMINED IN 3 SAMPLINGS —1 SQ. FT. EACH	PER CENT MORTALITY— 3 DAYS AFTER TREATMENT
Toxaphene, 45% emulsion, 2 lb.	102	7
BHC, 10% WP, 0.3 lb.	196	65
DDT, 50% WP, 3 lb.	213	46
Chlordane, 40% WP, 2 lb.	221	64
Parathion, 15% WP, 0.225 lb.	185	86
Parathion, 15% WP, 0.45 lb.	177	98
Check		
No treatment	176	0

Subsequent treatment of fields for commercial control using tractor-mounted low-gallonage spray booms using 0.3 pound parathion per acre gave excellent control of the larvae within 48 hours of application. It was evident that control depended on the amount of spray mixture used per acre since the amount of dead organic debris on the ground had to be penetrated for good control. Ten to 50 gallons of spray mixture per acre were used satisfactorily.

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Longevity of the Leafhoppers *Colladonus geminatus* (Van Duzee) and *Colladonus montanus* (Van Duzee) on Peach

D. D. JENSEN[1]

The geminate leafhopper, *Colladonus geminatus* (Van Duzee) has been shown to be a vector of the virus causing Western X-disease of stone fruits (Wolfe *et al.*, 1950), yellow leafroll virus of peach (Jensen *et al.* 1952) and aster yellows virus (Severin, 1934). *Colladonus montanus* (Van Duzee) is a species closely related to *geminatus* and also transmits aster yellows virus (Severin, 1934). Both species are widely distributed throughout the western states and are commonly encountered in many stone fruit orchards. However, the population ratio of the two species varies geographically. In the Sacramento Valley of California, *montanus* is much more common than *geminatus*. In contrast to this, *geminatus* appears to be the dominant species in the Pacific Northwest where it can at times be found in relatively large numbers on deciduous fruit trees as well as on herbaceous hosts. Osborn (1912) reported *geminatus* as being so abundant on clover, alfalfa and timothy in Washington that it was of pest status. Wolfe and Anthon (1952) report high populations of this leafhopper in central Washington where it breeds on alfalfa and other forage and cover crop legumes.

The number of breeding and food hosts of these leafhopper species in nature has not yet been adequately determined, but the range is apparently wide as indicated by the greenhouse studies of Frazier and Severin (1945). They reported that *montanus* and *geminatus* respectively completed their life cycles on 13 and 12 of 26 plant families tested, comprising 27 and 28 of 67 species of weeds. Of the plant species on which life cycles were completed, 20 species were common to both leafhoppers.

Since *Colladonus montanus* and *C. geminatus* are closely related, transmit at least one virus in common, and occur abundantly in some fruit growing areas, demonstration of *geminatus* as a vector of stone fruit viruses brings *montanus* under strong suspicion as a possible vector of the same viruses.

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This is particularly true for yellow leaf roll virus in the "peach bowl" of California where *montanus* is the numerically superior species. During greenhouse experiments with yellow leaf roll virus of peach, parallel tests were conducted with *C. geminatus* and *C. montanus* which revealed a striking contrast in the relative ability of the two species to survive when confined to peach.

Both species were reared on celery until many of the nymphs were in the last instar. On March 1, 1952, nymphs of both species were transferred to diseased peach trees where they fed for 2 days. They were then returned to celery and held until March 20. At this time five males and five females of each species were placed singly on seedling peach trees and were transferred each day to new plants. Fifteen males and 15 females of each species were placed singly on seedling peach trees on which they were left. The balance of each colony was maintained on celery.

Table 1.—Longevity of *Colladonus geminatus* (Van Duzee) and *C. montanus* (Van Duzee) adults on seedling peach trees in the greenhouse, under conditions of daily transfer to fresh peach trees.[1]

Species	Adult Survival on Peach in Days		Number of Individuals Tested
	Range	Mean	
geminatus ♂	65–101	86	5
♀	44–128	94	5
montanus ♂	1– 7	2.7	52
♀	1– 13	3.5	54

[1] *Colladonus geminatus* adults remained on the first test peach tree for 37 days and were transferred daily thereafter.

As is evident from table 1, adult *Colladonus montanus* survived for only a few days on peach in most instances. In the group being transferred daily to new plants, leafhoppers which died were replaced by individuals from the stock which was held on celery after the 2-day feeding on inoculum peach.

Colladonus geminatus, which proved capable of completing its life cycle on peach, also demonstrated that adults, reared on celery, can be transferred to and maintained on peach without any evident deleterious effects to the leafhoppers. The initial group of 10 *geminatus*, transferred daily to new trees, survived well until all were killed accidentally by being transferred to new trees just previously sprayed with TEPP (tetraethyl pyrophosphate). Therefore, on the 37th day after the experiment was started, a second group of 5 males and 5 females replaced the first group in daily serial transfers. These individuals had each been held on a single peach tree during the preceding 37 days. Accordingly, the figures listed for survival on peach in the case of *geminatus* represent 37 days on the first healthy peach and transfer to a new peach seedling on each day thereafter.

A trend seemed to be present in both species toward longer survival of the females than of the males. The survival of one *Colladonus geminatus* female for only 44 days on peach reduced the average considerably for the females in view of the fact that the other four survived for 90 days or more. However, a larger sample would be needed to establish a more stable mean. Survival may also be reduced in some instances by injury to the insects during daily transfers.

If *Colladonus montanus* is a vector of yellow leaf roll virus of peach, its poor survival on this plant is a possible explanation for failure thus far to prove the species capable of transmitting the virus. More suitable conditions for survival and virus transmission can be provided by giving this leafhopper feeding periods of 2 or 3 days on peach, alternated with similar periods on a more compatible host such as celery. By this method, both longer acquisition and transmission feeding periods can be achieved. Such an experiment, conducted during 1953, revealed that although adult *montanus*, reared on celery, do not survive long when confined to peach, they did oviposit readily in peach leaves during 2 to 4 day confinements on diseased trees. Large numbers of eggs hatched and the young nymphs were left on the diseased peach trees. There was little mortality during the early instars, and, although they survived on peach for several weeks, all of the nymphs died before reaching the adult stage.

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Damage to Carpet Materials by Silverfish

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It has been known for many years that domestic species of silverfish damage a variety of materials of both plant and animal origin found in homes, libraries, museums and warehouses. However, little information has been published on natural and synthetic fabrics attacked by the various species of silverfish.

Back (1937) showed that silverfish, *Lepisma saccharina* L., eats holes in thin fabrics, particularly those of rayon, and that any starched clothing will be attacked. Mallis (1941) determined that *Ctenolepisma urbana* Slabaugh fed on linen, rayon, cotton and lisle, but that feeding on silk and wool was negligible.

No published work could be found on potential damage to carpet materials by silverfish. Therefore, to determine if such materials would be attacked by

domestic silverfish, the following study was undertaken.

METHODS.—A preliminary test was set up in which 10 adult *Ctenolepisma quadriseriata* (Pack.) were placed in a petri dish with fibers of pure undyed carpet-type viscose rayon.[1] This same procedure was repeated employing undyed carpet-type wool and undyed carpet-type cellulose acetate as the test materials. No other food was included in the dishes. The fibers in each dish were weighed before and after feeding, to determine the amount of fiber consumed.

Following this series of experiments, another was conducted in which 10 adults were fed on small pieces cut from dyed and woven carpet samples. One sample of rayon, one of wool and one of cellulose acetate each approximately 20 mm. by 5 mm. were placed in separate dishes and 10 insects added to each dish. No other food was available to the insects. Determination of the amount of feeding done on the nap of the sample was used as the criterion of damage. The latter experiments were repeated except that whole wheat flour was added to each dish as an additional food source.

RESULTS.—The results are shown in table 1. Over a period of 2 months, the approximate weight of the undyed rayon consumed by the 10 insects was 60 mg.; of the wool, 15 mg.; and of the acetate, apparently none.

In the second series of tests, using dyed and woven material, evidence that feeding had occurred could be readily ascertained by the colored feces of the insects caused by the dye. When the dyed and woven carpet materials were available to these pests, the only difference in feeding noted was the amount of damage done to the wool. This was classified as slight. However, the fibers of the viscose rayon were completely eaten down to the backing material. In the final test, even though other food was available, approximately two-thirds of the piece of rayon carpet was eaten over a period of 2 months.

The experiments utilizing woven carpet materials alone and with whole wheat flour were repeated employing the firebrat, *Thermobia domestica* (Pack.), as the test insect. The results obtained were similar to those shown in table 1.

Table 1.—Damage to various carpet materials by *Ctenolepisma quadriseriata* (Pack.)[1] over a period of 2 months.

CARPET-TYPE MATERIALS	UNDYED	DYED AND WOVEN	DYED AND WOVEN PLUS WHOLE WHEAT FLOUR
Viscose rayon	Heavy (60 mg.)	Heavy	Heavy
Wool	Medium (15 mg.)	Slight	None
Cellulose acetate	None	None	None

[1] Ten insects were used in each petri dish.

CONCLUSIONS.—Viscose rayon was particularly attractive to the two pest thysanurans used. Wool was not damaged, if other food was available and cellulose acetate was not damaged at all.

The attractive ingredient in the viscose rayon carpet was the rayon itself and not the dye.

No evidence was found to show that the dye in the three materials employed was attractive to *Thermobia domestica* or *Ctenolepisma quadriseriata*.

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[1] All materials employed were donated by the Bigelow Sanford Rug Company, Thompsonville, Connecticut.

EDITORIAL

State Surveys in Relation to National Insect Problems

The states have a moral if not direct responsibility from the national standpoint in the matter of conducting reasonable surveys to determine the possible presence within their borders of major insect pests of major crops, not yet recorded in the country, or, if reported, not widely established. At least they would seem to have such responsibility with respect to those species which are the subject of foreign or domestic quarantines or, for that matter, the subject of interstate quarantines. Such effort and findings are of concern not only to the individual state but to all other states and to the nation as a whole, in planning effective safeguards or delaying action against their further spread or in accomplishing their eradication where desirable and feasible.

Safeguards at both state and federal levels are, all too often, established on political lines rather than with respect to existing barriers to natural spread. They are usually initiated without a full knowledge of where the species may occur. In following political lines, such safeguards are necessarily restricted to those areas in which infestation has been recorded. The safety afforded against pest spread by such procedure is obviously proportional to the effort expended in survey to determine the areas of occurrence. Failure to carry out such surveys has often allowed some one state to enjoy extended immunity from safeguard restrictions that otherwise might be imposed against the free movement of their products. This is particularly true with respect to interstate quarantines.

A typical example of such a situation is that which concerned the oriental fruit moth in the early 40's. The importance of this insect as a major pest of deciduous fruits had been demonstrated and its distribution east of the Mississippi River found to be sufficiently widespread that it was the subject of interstate rather than federal domestic quarantine. In the absence at that time of any effective control measures the western states were particularly interested in preventing its further spread westward. Following a uniform state policy, safeguard measures were established only against those states in which its occurrence was recorded. It seemed perfectly safe to accept potential host carriers from all other states.

In the meantime, the oriental fruit moth was being intercepted repeatedly at California border stations in fruit reported by owners to have originated in states in which it was not known to occur. It was not until federal effort was enlisted in surveying other states for its presence that it was found to be also fairly well distributed over the western half of the United States. As a result of these findings a quarantine was removed from the books. At the same time an important fruit producing area became infested with a major pest much sooner than would have occurred had a nationwide survey been encouraged at the state level.

It would be interesting to know how many states are making any concerted effort of their own to determine whether they have within their borders any of the insect pest species now attracting national attention, such as the golden nematode, European chafer, Asiatic garden beetle, white-fringed beetle, and others. How many states are waiting until some federal agency initiates such a survey, hoping that it will be put off as long as possible so as to avoid the restrictions that the findings may impose? Undoubtedly many states are inhibited against searching for any new pests within their borders, as they may already be confronted with more major pest control problems than they can handle. And yet the information that might be developed through directed state survey might be exceedingly important from the national viewpoint as well as to other states.

Oddly, the finding of new insect species of economic importance is seldom the result of direct survey for that species. More often it is the result of general survey or of that directed towards some other species. The presence of the oriental fruit fly in Hawaii was discovered during the examination of routine trap collec-

tions concerned with other species. The oriental fruit moth was first found in California in peach on a yard tree in a district given over to the production of citrus fruits, during survey for Mexican fruit fly; Mexican bean beetle was reported for the first time in the state by a grower through a crew surveying for red scale in a nearby citrus orchard. New infestations of citrus whitefly have repeatedly been found on ornamentals while searching for olive scale. If the facts were known the history of important findings in other states has undoubtedly been similar. The important fact is that they were found as a result of survey.

There is always the possibility that a new pest species may make its first appearance in the country in the most unexpected places and from the most unexpected sources. Usually, when discovered by accident, such infestations have reached a stage which has permitted jump spread which under the same conditions would not be discovered until it, in turn, had been responsible for similar spread. There is, therefore, also the possibility that they would not be discovered until too well established to permit eradication, unless some form of directed survey was being regularly followed. The alfalfa weevil apparently jumped from the shores of the Mediterranean to Utah. The Japanese beetle and the oriental fruit moth, both from the Orient, jumped over the western states to become first established in Washington, D. C. The sugar beet leafhopper apparently jumped from Spain to the western states via Mexico. None of these was discovered in time to permit consideration of eradicative measures. Proximity to potential source would seem to have no bearing on the direction or extent of established spread where foreign pests are concerned.

Border states are often confronted with the conduct of insect pest surveys for their own protection, the results of which may be of equal or even greater benefit to other states or to the nation as a whole. The recent finding of the oriental fruit fly in the Hawaiian Islands is a typical example. The initial population of flies following its introduction into a very favorable habitat in the absence of any natural enemies was so tremendous that there was every possibility of its finding its way to the mainland in spite of the effective quarantine measures being rigidly enforced. California being the nearest point of contact was faced for several years with the carrying out of an expensive trapping survey to detect any such introduction. Subsequently it was determined, through the use of climate cabinets by federal research workers in the Islands, that the fly had more possibility of being a pest in Florida than in California, though it might well survive in the latter state. Fortunately, the situation has been relieved by the introduction of parasites into the Islands which have now reduced the number of flies to a level where they represent no greater hazard of introduction than does any other insect.

The survey in California was made in the full knowledge that if a single fly were found it would have to be interpreted as indicating an established infestation, as far as other states were concerned. To be consistent with the action taken against the Hawaiian Islands, embargo type quarantines would have had to be established at the federal level. These would have restricted the free movement of fresh fruits and vegetables usually moving in volume to other states, and would at least have temporarily demoralized an industry which is basic in that state. Nevertheless it was deemed more important to detect any incipient infestation in sufficient time to permit the application of eradication measures with some reasonable expectancy of success.

Periphery survey, at least, is an integral part of any eradication or control project directed against any specific insect pest such as the pink bollworm of cotton or the white-fringed beetle. Such action is essential to assuring that the contiguous infested area has been contained within the area of eradication effort. It is equally important that regular, uniform surveys be conducted in all states where the host or hosts concerned are grown, to assure that the effort is serving a real purpose. This would reasonably seem to be a function of the states concerned.

California has a law which makes it mandatory that any representative of an official agency, such as the Department of Agriculture, University or Extension Service, who finds an insect species new to the state shall immediately report it to the regulatory officials. They, in turn, make all such information available to the Divi-

sion of Insect Detection and Identification, in Washington, D. C., which, in turn, makes it available to all of the states. Also, specimens are filed with the Division of Insect Detection and Identification in Washington for confirmation. If similar procedure were followed in all states, all concerned would be in a better position to meet insect problems as they develop and possibly to prevent many of them ever reaching major importance.

Several years ago insect pest survey, by legislative commitment, became a permanent activity of the California Department of Agriculture. The state was divided into three geographical areas and a competent survey entomologist assigned to each area, working under a supervising survey entomologist who plans and assigns the work. The primary work of each, however, is not to look for new pests, themselves, but to train and encourage the over five hundred available, widely distributed, local regulatory officials in how, where, when, and what to look for. In so doing the local worker is made pest survey conscious and, with the state leader's assistance and with his own knowledge of the area and its agriculture, the work has been productive of very favorable results. It has also been responsible for uniformity of action throughout the state and made it possible to direct attention at a moment's notice to any special survey problem.

A similar procedure has been established at the federal-state level in which survey entomologists have been assigned by the Bureau of Entomology and Plant Quarantine to each of the five regions into which certain operations of that Bureau have recently been divided. Their duties are primarily to encourage the states to engage in survey for insect species in general or specifically. This cannot help but lead to greater uniformity of action at the state level particularly with respect to specific pests. It can materially extend the area and intensity of survey over that possible at the federal level and will give the states a definite part in developing the over-all information on which sound quarantine action can be taken or effective eradication or control measures attempted. Favorable results from this arrangement are, however, completely dependent on the wholehearted, sincere cooperation on the part of the states.

Increases in population, in the means and speed of transportation and in the diversity of interests of world travelers are all conducive to the increased spread of insect pests. Only by directed survey at the state level can we expect to assist the federal authorities and each other in meeting this challenge.

California always has welcomed and will continue to welcome federal assistance in making her own insect pest surveys and invites independent effort on their part if it will better serve the interests of other states and the nation.

H. M. ARMITAGE

OBITUARIES

Deed Cleveland Thurman, Jr.
1921-1953

Deed C. Thurman, Jr., died on April 18, 1953, in Chiengmai, Thailand, after a short illness. As a Sanitarian, commissioned in the United States Public Health Service, he was assigned to the Mutual Security Agency as Malaria Control Advisor for the Northern Region of Thailand; and after serving in that capacity for two years, would have left with his family in just nine days to return home, had not death intervened.

There were funeral services at the Presbyterian Mission Chapel in Chiengmai followed by Bhuddist ceremonies at the American consulate; and then the body was flown to the States for services and burial in Menard, Texas, where Deed was born January 24, 1921.

He attended Texas A. and M., majored in entomology, and in 1942 received a Bachelor's degree in Agriculture; that same year, he went to work for the Texas State Department of Health. In 1944, he was commissioned in the U. S. Public Health Service, and served as entomologist in the Office of Malaria Control in War Areas and the Communicable Disease Center. His duties took him to Oklahoma, Georgia, and finally to Florida, where he was assigned as the Communicable Disease Center's entomologist for the State to work in cooperation with the Florida State Entomologist's organization. In 1949, he transferred to California, where he attended the University of California, received the degree of Master of Public Health, and headed the Central Valley Mosquito Control Ecology project at Turlock, California. For two years he worked indefatigably on the essential biological factors underlying the production and disperison of *Aedes nigromaculis*, *A. dorsalis*, and *Culex tarsalis* mosquitoes. The work which he began in 1949 is continuing; his industry and foresight laid the groundwork for an organization known as the State's Vector Control Field Station. California appreciated Deed's keen biological insight and application to his task, and was looking forward to the time when he would return after his tour of duty overseas.

In March, 1951, Deed Thurman left for Thailand, to be joined about three months later by his wife, Ernestine, who was his constant companion and fellow entomologist, and their five-month old daughter. They settled in Thailand for two strenuous but productive years. His unassuming competence won for Deed the admiration and respect of those with whom and for whom he labored; and, referring to his accomplishments, a close associate, Dr. Udaya Sandhinand, Chief Malaria Control Officer for the Northern Province, wrote:

"His untimely death was a great shock to not only his Thai friends, but to those who knew about his efforts put into the work assigned for him. Though his body and soul have left his loved ones, his work in Thailand for the Thai people will long live and forever be in their memories."

Mr. Thurman was the author of some forty papers covering most insects of medical importance, their control, epidemiology, and aspects of their disease transmission. He was a member of many scientific organizations, including two in Thailand, the Entomological Society of America, American Mosquito Control Association, American Society of Tropical Medicine and Hygiene, American Public Health Association, California Mosquito Control Association, Florida Anti-Mosquito Association, American Society of Professional Biologists, American Society of Parasitologist, and the Research Society of America.

He is survived by his wife, Ernestine, a daughter, Phyllis, a son Charles, by a previous marriage, his mother and father, and a sister. Deed C. Thurman, Jr., lived only a few years, but he lived them fully and wisely; he established himself firmly in the hearts and memories of numerous friends throughout the world, who mourn his passing but are grateful for the opportunity of knowing him.

HELEN LOUISE TREMBLEY

Charles Carlton Plummer
July 1907-April 1952

This is not a record of a man's death but a tribute to his life. Although Dr. Plummer's life was not a long one, it was of benefit to two countries. Plummer's working career was spent almost entirely in Mexico. The formula he perfected and proved for the citrus blackfly continues to eradicate new outbreaks of that disastrous pest. Plummer's singleness of purpose, his devotion to scientific truth and his loyalty to his friends will be remembered always by those of us who worked with him. And the translation of a letter received from Ing. Manuel Moreno Torres, President, during Plummer's life, of the Comité Nacional de Combate y Control de la Mosca Prieta de los Cítricos, and now Director General de Obras Públicas del Distrito Federal of Mexico, will give more clearly than I can what Plummer's life has meant.

DIRECTOR GENERAL DE OBRAS PUBLICAS
DEL DISTRITO FEDERAL

My excellent and distinguished friend:

It is a singular honor you confer upon me in your kind letter of the 15th in inviting me to commemorate in a few lines the eminent entomologist, Dr. Charles Carlton Plummer, and it gives me an occasion for fu filling a duty as a Mexican, as a colleague, and as a friend, a privilege and an opportunity for which I thank you cordially and sincerely.

To extol, at all times, the memory of those who devote their existence to the service of humanity in fruitful and concentrated effort, to the extent of dedicating their lives to that ideal, is to place above the egotism that surrounds this period, an egotism that appears to be its norm and its interpretation, to place above it the highest and noblest values of the spirit which are the motor pathways that carry the finest elements of progress to the entire world.

And in this legion of unsung heroes of science, whose deepest desire is, always, to serve their fellowmen, Dr. Plummer, our departed colleague in the campaign against the citrus blackfly, holds an outstanding place, by right of pre-eminence, for his wisdom and his sacrifice.

As President of the Commission that has been responsible in my country for directing the campaign against such a lamentable pest, I shall never forget Dr. Plummer's many experiments in the use of in-

CHARLES C. PLUMMER

secticides and fungicides, conducted by elimination, and the results of which, together with biological control, have opened the roads to the present effec tive fight against this devastating pest; and if his life, as a noteworthy paladin of entomology produced an abundant fruit of knowledge, his passing consecrates him as an example of perfection and achievement.

For this reason I consider it an inestimable honor, my esteemed Dr. Baker, to write these lines in memory of him who shared with us the task of fighting the pest which bid fair to bring ruin to the entire citriculture of Mexico.

Moreover, you have given me the opportunity, as I have already mentioned, to fulfill a special duty in my character as a Mexican since without other merit on my part to speak in the name of my country than that I presided over the Commission in charge of the campaign against the citrus blackfly, I fervently render homage, recognition and gratitude to the memory of Dr. Plummer because the best of his knowledge and his efforts were placed at the service of Mexico—my Country.

And by the same token I recall with affection the affable man and exemplary gentleman whom I had the high privilege of having as a friend.

I remain Dr. Baker—

Very cordially yours,
Ing. Manuel Moreno Torres(s)

With a B.S. from Connecticut State College, an M.S. from New Hampshire, and a Ph.D. from Ohio State, Plummer concentrated his knowledge and effort on his work. But he found time to be a leading spirit in the Boy Scout movement in Mexico and the memory of that spirit remains vivid in the hearts of many. Coming to Mexico in 1930 his life was spent on the Mexican bean beetle, the Mexican fruit fly, and the citrus blackfly. He was married in Mexico and his children were born in Mexico. His wife, Mrs. Evelyn E. Plummer and his children, Mrs. Kenneth Saylor, Charles Carlton Plummer, Jr., and Sandra Plummer survive him.

A. C. BAKER

Hiraharu Yuasa
1900-1953

The many friends of Dr. Hiraharu Yuasa will be shocked and grieved to learn of his untimely death on October 21, 1953, at the age of 53. He received his formal education at Tokyo Imperial University where he was one of the first students of Dr. Tokio Kaburaki, noted Japanese Zoologist.

The lack of recent entomological contacts between Japan and the United States made it appear desirable during the Occupation that an entomologist from Japan visit the United States. Dr. Yuasa was selected as the most logical person for that mission. He visited the Bureau of Entomology and Plant Quarantine, U. S. National Museum, the Agricultural Research Center, Beltsville, Md., and a number of selected experiment stations, from January to April 1950. He became an affiliate member of the American Association of Economic Entomologists during that visit. Dr. Yuasa's personality and friendly nature attracted people with whom he came in contact and he made a host of friends.

Returning to Japan full of enthusiasm from his trip, Dr. Yuasa resumed his duties as Chief of the Section at the National Institute of Agricultural

Sciences, Nishigahara, Tokyo. Naturally of a somewhat frail constitution, apparently his trip to the United States overtaxed his strength and shortly after his return to Japan Dr. Yuasa became ill and had to relinquish his duties for several months of recuperation. After returning to his post he was made Chief of General Affairs, the duties of which occupied most of his time, but he continued his interest in his selected specialty, entomology. He attended the 9th International Congress of Entomology held at Amsterdam in 1952 as one of the representatives from Japan.

Dr. Yuasa was on a trip to assist with some research work when he became ill, quickly lapsing into a coma from which he never recovered. Although his family were rushed to his bedside he did not recognize them. He died the following morning.

Needless to say Japan has lost one of the guiding lights in entomology and the loss will be keenly felt.

RAYMOND ROBERTS

BOOK REVIEWS

LIST OF SUGAR-CANE INSECTS. A Synonymic Catalogue of the Sugar-Cane Insects and Mites of the World, and of their Insect Parasites and Predators, arranged systematically, by Harold E. Box, Commonwealth Institute of Entomology, 41, Queen's Gate, London, S.W.7. 1953. 101 pp. Price 15/-(U. S. $2.25) post free.

This book should be of particular interest and value to all persons whose work brings them into practical contact with sugarcane. The author's long association with sugarcane insects in the British West Indies and Latin America and his prominence in entomology assure its authenticity and soundness. This list brings together in a convenient form available records of sugarcane insects, their parasites, and their predators, which may be used as a working index to the names appearing in the literature of sugarcane entomology. Special attention has been given to various alternative names under which each insect has been recorded and the name ultimately selected conforms with the most recent taxonomic work. A species may readily be traced under any of its names by means of cross-references. Part I gives the order, family, genus, and species of each sugarcane insect, the country where the insect has been observed feeding on sugarcane, and by genus name only its parasites and predators. Part II lists in similar order the parasites and predators along with their host or prey and the countries in which such parasitism or predatism is known. A bibliography, a systematic index and an index to countries round out the work. Mr. Box is to be congratulated on this fine and extremely useful contribution.

RALPH MATHES

INSECT, FUNGUS AND WEED CONTROL, by E. R. deOng. Chemical Publishing Co., Inc., 212 Fifth Ave., New York 10, N. Y. 1953. 8½×5½ inches, 400 pages, 37 figs. $10.00.

Dr. deOng has produced a concise, authentic volume covering in 17 chapters, insect, fungus and weed control principally by the various organic compounds developed since the beginning of World War II. However no useful inorganic insecticide, fungicide or herbicide has been neglected. There are chapters on the physical properties of dusts and sprays; equipment; labeling; organic and inorganic insecticides and fungicides; the use of mineral, vegetable and animal oils; fumigants; plant derivatives such as nicotine, rotenone, pyrethrum; disinfectants for seeds; herbicides. These chapters that deal principally with chemical composition, application and effectiveness are followed by four final chapters on the control of forest insects and diseases, livestock insects, mites, ticks, household insects, rodents, and the use of industrial insecticides and fungicides. Recent developments are included in an appendix, the whole being followed by an index. Dr. deOng, a consulting entomologist and agricultural technologist for many years and an insecticide specialist, has compressed in this book an enormous amount of information, useful to everyone who has anything to do with pest control. No words are wasted and only essential information is presented.

H. B. WEISS

PROCEEDINGS OF THE FIRST ANNUAL MEETING

PACIFIC BRANCH
ENTOMOLOGICAL SOCIETY OF AMERICA

Lake Tahoe, California, June 23, 24, 25, 1953

The first annual meeting of the Pacific Branch of the Entomological Society of America (which corresponds to the thirty-seventh meeting of the Pacific Branch of the previous American Association of Economic Entomologists) was held at Lake Tahoe, California, June 23, 24, and 25, 1953. The officers during the meeting were: STANLEY F. BAILEY, *Chairman;* A. W. LINDQUIST, *Vice-Chairman;* and LESLIE M. SMITH, *Secretary-Treasurer.* The Chairmen of the various committees were: R. F. SMITH, *program;* R. W. UNDERHILL, *arrangements;* MRS. MARGARET BOHART, *arrangements for ladies;* E. O. ESSIG, *registration;* A. F. SWAIN, *operations;* W. M. HOSKINS, *resolution 5,* 1950; A. E. MICHELBACHER, *membership;* H. M. ARMITAGE, *resolutions;* A. J. FLEBUT, *press;* and W. EBELING, *nominations.* Acting chairmen at various times during the meetings were S. F. Bailey, M. C. Swingle, J. E. Swift, F. V. Lieberman, R. F. Smith, R. W. Underhill, and A. W. Lindquist.

The meeting was opened by an address by DR. CHARLES E. PALM, *President* of the Entomological Society of America, who discussed the new Society and the advantages of amalgamation. He commented favorably on the wide breadth of subject matter now presented in Branch meetings. DR. AVERY S. HOYT, *Chief* of the Bureau of Entomology and Plant Quarantine, U.S.D.A., presented an interesting, invitational paper entitled "The Future Development of the Bureau of Entomology and Plant Quarantine."

Panel discussions and symposia were as follows:

Recent Research Projects of the Pacific Science Board in the Field of Entomology. H. J. COOLIDGE, presiding, C. E. PEMBERTON, J. L. GRESSITT, A. P. MESSINGER, W. H. LANGE, and R. L. USINGER.

The Evolution and Development of a New Insecticide. W. M. HOSKINS, moderator, R. H. WELLMAN, F. C. BISHOPP, S. B. FREEBORN, F. R. BARRON, A. B. LEMMON, M. P. JONES, and A. J. FLEBUT.

Cooperation Between Research Workers, the Extension Service and Industry. J. E. SWIFT, moderator, L. A. CARRUTH, R. D. EICHMAN, G. F. KNOWLTON, G. F. MACLEOD, P. O. RITCHER, and M. SWOBODA.

Control of Ectoparasites of Livestock. D. P. FURMAN, moderator, R. C. BUSHLAND, R. W. EVERY, G. F. KNOWLTON, A. W. LINDQUIST, H. C. MANIS, and R. PAINTER.

Recent Developments in the Control of Forest Pests in Western United States and Canada. F. P. KEEN, moderator, L. W. ORR, H. A. RICHMOND, N. D. WYGANT, R. L. FURNISS, and R. Z. CALLAHAN.

The Development of Entomology in the West. M. H. HATCH, V. M. TANNER, and E. O. ESSIG.

Absorption and Translocation of Insecticides in Plants. W. H. LANGE, moderator, A. S. CRAFTS, R. T. WEDDING, R. L. METCALF, E. E. IVY, H. T. GORDON, R. C. SCOTT, S. C. DORMAN, L. R. JEPPSON, E. S. SYLVESTER, W. EBELING, and W. S. JAMES.

In addition to the invitational paper and symposium papers (totaling 51 speakers) there were 40 submitted papers. For the first time in any meeting of the Pacific Branch it was necessary to hold concurrent paper reading sessions during one afternoon, and to continue paper reading on one evening. Seven motion pictures were repeatedly shown concurrently with the paper reading sessions.

At the preliminary business meeting Chairman Stanley Bailey made the necessary announcements and Secretary Leslie M. Smith passed out copies of the proposed changes in the Constitution of the Pacific Branch as follows:

PROPOSED CHANGES IN THE CONSTITUTION OF THE PACIFIC BRANCH

1. Title (none previously) Constitution of the Pacific Branch of the Entomological Society of America.
2. Change Article I, Sec. 1, to read: "This branch of the Entomological Society of America shall be known as the Pacific Branch."
3. Change Article II, Sec. 1, to read: "All members of the Entomological Society of America residing in . . . are members of the Pacific Branch."
4. Change Article III, Sec. 3, to read: "The Executive Committee shall choose one of its members, by a majority vote, to represent this Branch on the Governing Board of the Entomological Society of America."
5. Change Article IV, Sec. 1, to read: "Annual meetings shall be held at a time and place which shall be selected by the Executive Committee."
6. Change Article V, Sec. 1, to read: " . . . operate under the provisions of the Constitution of the Entomological Society of America."
7. Article VII, Sec. 1, delete "Place-of-meeting" committee, since this function is better administered by the Executive Committee.

At the final business meeting the constitutional changes were passed unanimously. The membership accepted and passed the following reports:

REPORT OF THE COMMITTEE ON RESOLUTION 5 OF THE 1950 MEETINGS

Whereas, the rapid finding of chemicals which have useful properties in protection of animals and plants shows no sign of lessening, and

Whereas, it is generally agreed that new pesticide chemicals should not come into general use until restrictions on the amounts remaining on foodstuffs have been established, and,

Whereas, the expensive and time-consuming procedure of showing necessity for use by public hearing cannot be used with sufficient frequency, and

Whereas, three years after a long and expensive hearing, no tolerances have been announced, be it

. *Resolved,* that the Pacific Branch of the Entomological Society of America in business session on this 25th of June, 1953, urges upon all appropriate agencies and authorities that this unsatisfactory condition be improved as speedily as possible by the adoption of laws or regulations which will provide for

any interested party to petition for the establishment of a tolerance for a pesticide chemical, for the Secretary of Agriculture to certify regarding its usefulness for the specified purpose, for the securing of impartial advice from experts in the subject matter, and for the prompt issuance of a tolerance, with the right of any interested party to file objections and to have recourse to the established courts.

C. C. CASSILL
L. CHILDS
D. W. DEAN
F. A. GUNTHER
A. B. LEMMON
W. M. HOSKINS, *Chairman*

TREASURER'S REPORT

		Debits	*Credits*
June 23, 1952	Balance in treasury		$187.36
June 23	Registration fees		333.00
July 8	Postage on films, Check 36	$ 3.80	
July 31	Refund on entertainment, Check 37	38.11	
Aug. 26	Rental on films, Check 38	4.32	
Feb. 18, 1953	Stenographic, Check 39	2.50	
Feb. 19	Stenographic, Check 40	2.50	
Mar. 23	Announcements, Check 41	24.10	
May 8	Stamped envelopes, Check 42	27.51	
June 15	Mailing programs	45.00	
June 18	Printing programs	205.49	
	TOTALS	353.33	520.36
June 26, 1953	Balance in treasury	167.03	
		$520.36	$520.36

LESLIE M. SMITH, *Secretary-Treasurer*

REPORT OF THE AUDITING COMMITTEE

We have examined the accounts of the Treasurer and find them to be correct.

ROY E. CAMPBELL, *Chairman*
L. D. ANDERSON
G. F. MACLEOD

The following report on membership in the Pacific Branch of the Entomological Society of America has been prepared by Dr. Leslie Smith. I wish to add a word of thanks and appreciation to the several members of the Membership Committee for the effective effort put forth in extending the membership of our society.

A. E. MICHELBACHER

REPORT OF THE MEMBERSHIP COMMITTEE

During the past year the Pacific Branch gained 210 new members. The Membership Committee enrolled 79 of these new members. The sources of new members were as follows:

Membership, Jan. 1, 1952[1]		808
New Members		
Members of old E.S.A. who became Branch members by consolidation[2]	73	
New Branch members, Jan. 1–Dec. 8, 1952[3] (This includes 12 new members enrolled by the current membership committee)	70	
New members enrolled by the current membership committee Dec. 1–June 22, 1953	67	
Total new members		210
Total members in Pacific Branch		1,018

L. A. CARRUTH
A. F. KIRKPATRICK
H. T. REYNOLDS
P. O. RITCHER
W. J. O'NEILL
A. E. MICHELBACHER, *Chairman*

REPORT OF THE RESOLUTIONS COMMITTEE

RESOLUTION NO. 1.

Whereas, the members of the Pacific Branch of the Entomological Society of America, their families, and guests, have enjoyed an excellent program of varied entomological subjects, and,

Whereas, this first annual meeting of the Pacific Branch of the amalgamated societies has provided an excellent opportunity to renew old friendships and to make new ones;

Bet it therefore resolved, that the membership express its appreciation to the following individuals and organizations who were responsible for the success of the meeting,

(a) To the program committee, R. F. SMITH, *chairman*.
(b) To the committee on arrangements, R. W. UNDERHILL, *chairman*.
(c) To the committee on arrangements for ladies, MRS. MARGARET BOHART, *chairman*.
(d) To the committee on registration, E. O. ESSIG, *chairman*.
(e) To all other committees, officers, and members who cooperated for the success of the occasion.
(f) To DR. C. E. PALM, *President* of the Entomological Society of America, and MR. A. S. HOYT, *Chief* of the Bureau of Entomology and Plant Quarantine, U.S.D.A., and all other guest speakers.
(g) To the many members of the insecticide industry who contributed generously to provide the excellent entertainment, and
(h) To ANDY ROBERTSON of the Lake Tahoe Convention Bureau and to CHUCK JOHNSON and NEIL OLSON of Conolley's Resort for the many courtesies and accommodations extended in making this meeting a success.

RESOLUTION NO. 2.

Whereas, the membership of the Pacific Branch of the Entomological Society of America has grown to a size nearly equal or greater than any other branch of the Society, and,

Whereas, the meeting scheduled in Los Angeles in 1953 represents an elapsed time of 12 years since the last previous meeting,

Be it therefore resolved, that the committee on long range planning of national meetings be requested to recognize this increased membership in the West by scheduling more frequent meetings in the area of the Pacific Branch.

RESOLUTION NO. 3.

Whereas, special academic training in entomology if not an actual degree, is required as a basis of employment where that science is involved and a permit, license, or other demonstrated eligibility to such service is required, and,

Whereas, most governmental and industrial agencies allow properly merited credit for such training or degree in lieu of experience in establishing eligibility for such employment, and,

Whereas, there are still a few important fields of employment involved which require but have been

[1] JOUR. ECON. ENT. **45**(1): 167–200, Feb. 1952.
[2] Annals Ent. Soc. Amer. **45**(1): 144–173, March 1952.
[3] JOUR. ECON. ENT. **46**(1): 194–196, Feb. 1953.

slow to recognize such training or degree and further require one or more years of experience or apprenticeship as a condition of employment,

Therefore be it resolved, that the Pacific Branch of the Entomological Society of America go on record as approving and recommending that basic college training in entomology, in an approved institution, where required as a condition of eligibility to employment, be accepted at least year for year, in lieu of otherwise required experience or apprenticeship.

E. M. STAFFORD
A. W. CRESSMAN
H. M. ARMITAGE, *Chairman*

The above three resolutions were adopted by the membership.

A fourth resolution, presented by the Resolutions Committee, as follows, was tabled:

Whereas, concurrent sessions, often held at widely separated locations, prevent the hearing of many important papers by members during transit from one session to another in an effort to hear those on subjects of particular personal interest, and

Whereas, concurrent sessions tend towards specialization and restriction to individual fields of interest preventing opportunity to present such material before the entire group which is adverse to the broader purpose of the organization, and

Whereas, the Pacific Branch of the Entomological Society of America would seem not yet to have attained a size making concurrent sessions necessary.

Therefore be it resolved, that future program committees be requested to give consideration to arranging meetings on a general session basis which it is suggested may be accomplished by:

(1) restricting the number of invitational papers to such as can be filled in with the number of submitted papers.
(2) discouraging multiple presentation of papers by the same author.
(3) generally restricting invitational papers to 20 minutes and to not more than 30 minutes where warranted, and restricting submitted papers to 10 minutes including slides
(4) advising speakers and panels in advance of their allotted time as programmed and holding them strictly to that time, and
(5) starting all sessions on time, regardless.

Chairman Bailey called for nominations from the floor to fill the vacancy on the EXECUTIVE COMMITTEE. MR. R. D. EICHMANN was nominated and elected to this office.

The nominating committee presented the following report and these candidates were duly elected:[1]

REPORT OF THE NOMINATING COMMITTEE

The nominating committee nominates officers for 1953–54 as follows:

Secretary-Treasurer: LESLIE M. SMITH. We are departing from the usual custom in offering the name of the candidate for Secretary-Treasurer as the first nomination as a tribute to the outstanding performance of his duties during the last five years. Dr. Smith has undertaken many obligations beyond the ordinary call of duty of his office in an outstanding manner and we are indeed fortunate in being able to prevail upon him to accept this important office for the coming three years.

Chairman: ARTHUR W. LINDQUIST.[1] We are happy to follow the precedent of many years in nominating the Vice-Chairman of the past year as Chairman.

Vice-Chairman: JOHN B. STEINWEDEN. It has been the custom to nominate, in more or less of a rotation, candidates for this office from the U.S.D.A., universities, states, counties and industry. During the last ten years four candidates have been selected from the universities, two each from the U.S.D.A. and industry and one each from the states and counties. It appeared from the record that the selection of a candidate from a state or county office would be appropriate this year.

In addition the By-Laws state that the Chairman should be from the region selected for the annual meeting for the year of his chairmanship. In the past the Pacific Northwest, Northern California and Southern California or Arizona have been selected in rotation as the site of the annual meetings.

The present committee has taken its task very seriously. Probably about half of the members have been approached for their views as to the suitable Vice-Chairman in view of the above considerations. It is the consensus of the Nominations Committee that MR. JOHN STEINWEDEN would serve admirably in this capacity.

I move the nominations be accepted.

Respectfully submitted,
E. H. LITTOOY
J. N. RONEY
W. EBELING, *Chairman*

Dr. J. F. Kagy moved that the Pacific Branch contribute from its treasury fifty dollars to the entertainment fund for the National meetings of the Entomological Society of America in December 1953 in Los Angeles. This motion was seconded and passed.

The members enjoyed a banquet, floor show, and dance. Entertainment for the ladies consisted of a boat trip to Vikingsholm on an island in Emerald Bay and a bus trip to Virginia City. A hog dog barbecue was held for the children on the beach. A total of 281 members and guests registered, and wives and children brought the total attendance to 452.

[1] A. W. LINDQUIST was subsequently transferred to Washington, D. C. and submitted his resignation as Chairman of the Pacific Branch. The *Vice-Chairman*, JOHN B. STEINWEDEN, waived chairmanship at this time in order to accept in 1955 when the meeting will be held near his residence. The Executive Committee therefore was faced with the necessity of selecting a new Chairman, and by a majority vote this Committee selected DR. STANLEY B. FREEBORN as *Chairman* for the current year.

THE ROCKY MOUNTAIN CONFERENCE OF ENTOMOLOGISTS, 1953

The twenty-fourth Rocky Mountain Conference of Entomologists was held in the Colorado A & M College Forestry Summer Camp in Pingree Park about 55 miles west of Fort Collins August 23–27, 1953. The accommodations and arrangements permitted the giving to members of families a mountain outing while the meetings were in progress. A total of 152, representing 17 states, registered in camp with 68 of those being directly interested in entomology. The evenings were given largely to entomological pictures, educational pictures of general interest, a few cartoons for the kiddies, square dancing, and other activities into which all members of families could join. No formal papers were presented. All programs took the form of discussions. The following are the more important topics with the leaders selected to open discussion.

General Subjects
- Insect detection and reporting: Kelvin Dorward, J. I. Couger, Leonard Haseman, L. B. Daniels, and H. C. Severin.
- European and American foul brood and other bee problems: Joe Moffett, Leonard Haseman, C. J. Walstrom, and W. W. Franklin.
- Aphid trapping and mounting: E. O. Essig.

Field Crop Insects
- Corn ear worm: R. R. Walton.
- Southwestern corn borer: Ken Arbuthnot, F. E. Whitehead, Christ C. Burkhardt, and W. W. Franklin.
- Soil insecticides: Chris C. Burkhardt, W. W. Franklin.
- Alfalfa weevil: T. R. Robb and J. H. Newton
- Wheat stem sawfly: R. H. Painter.
- Mosaic disease of wheat: Hurley Fellows and R. H. Painter.

Stored Grain Insects
- C. J. Walkton, William Finlay and R. T. Cotton.

Parasites of Man and Animal
- Cattle grub control on a regional basis: H. C. Severin.
- Cattle lice control: Gene De Foliart.
- Ectoparasites of rodents in relation to rodent-borne diseases: Harvey Morlan.
- Encephalitis studies—progress report: Clarence Sooter.
- Rice land mosquitoes: F. E. Whitehead.

Insecticides
- Hazards and precautions: J. M. Magner, D. M. De Long, and J. W. Dean.
- New insecticides and new uses for old ones: J. M. Magner, John Brandenburg, W. F. Cherry, William Finlay, R. J. Fuxa, John Gibson, Eugene Kenaga, Louis Hamman, C. R. Hunt, Sam McCampbell, Philip Marvin, and Jim Maxwell.

Forest and Shade Tree Insects
- Forest insect investigations: Noel Wygant.
- The status of the Englemann spruce beetle and other forest insects in the Rocky Mountain Region: Bill H. Wilford.
- Forest insect pest surveys by airplane: Fred B. Knight.
- Trap logs for spruce beetle control: Roy Nagel.
- Radioisotopes in tracing bark beetle flights: Roy Nagel.
- The gouty maple leaf vein gall gnat: Leonard Haseman.
- Hopper burn on caragana: H. C. Severin.

Fruit and Vegetable Insects
- Fruit pests of 1953: J. H. Newton.
- Seed corn maggot on spinach: R. R. Walton.

The following were officers for the 1953 conference:

Chairman: W. W. Franklin
Vice-Chairman: Wm. J. Finlay
Treasurer: John L. Hoerner
Assistant Treasurer: T. O. Thatcher
Secretary: Geo. M. List
Assistant Secretary: Gordon Mickle

Those elected to arrange for the 1954 conference were Chairman: D. M. DeLong; Vice-Chairman: Noel Wygant, with the other officers as for 1953.

GEO. M. LIST, *Secretary*

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* Compiled by Joe S. Wade.

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Hexachloro-benzene	Seed Disinfectant
*LINDANE	99% Gamma Isomer of BHC

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This highly adsorbent carrier has been developed by the Floridin Company for the processing of impregnated concentrates. Originally recommended for toxaphene and chlordane formulations, DILUEX-A has found preference for more varied uses. Ease of handling, increased output, and an improved final product commend it in grinding and blending operations. Customer satisfaction confirms the choice. Adequate unfailing supplies of DILUEX-A is a practical consideration. Take a look at the following data and ask for any further information that you would like.

Properties of DILUEX-A

Color: Light grey to cream
Composition: Aluminum magnesium silicate (Florida Fullers Earth)
Bulk: 19 to 21 lbs. per cubic foot, loose
33 to 36 lbs. per cubic foot, packed
Mesh: 90 to 95% finer than U. S. 325
Specific Gravity: 2.2 to 2.4
Surface Mean Diameter: 1.5 to 1.7 microns
pH: 6.8 to 7.1 (AOAC method)
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DDT (dusts, wettable powders, sprays)
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LINDANE (dusts, wettable powders, spray)
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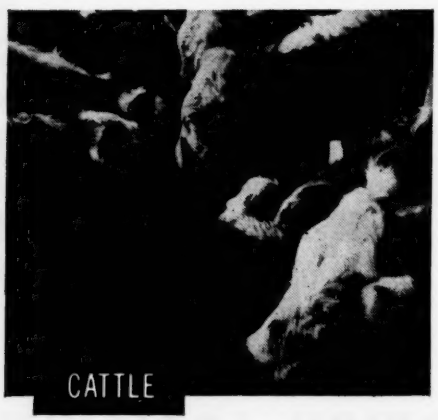
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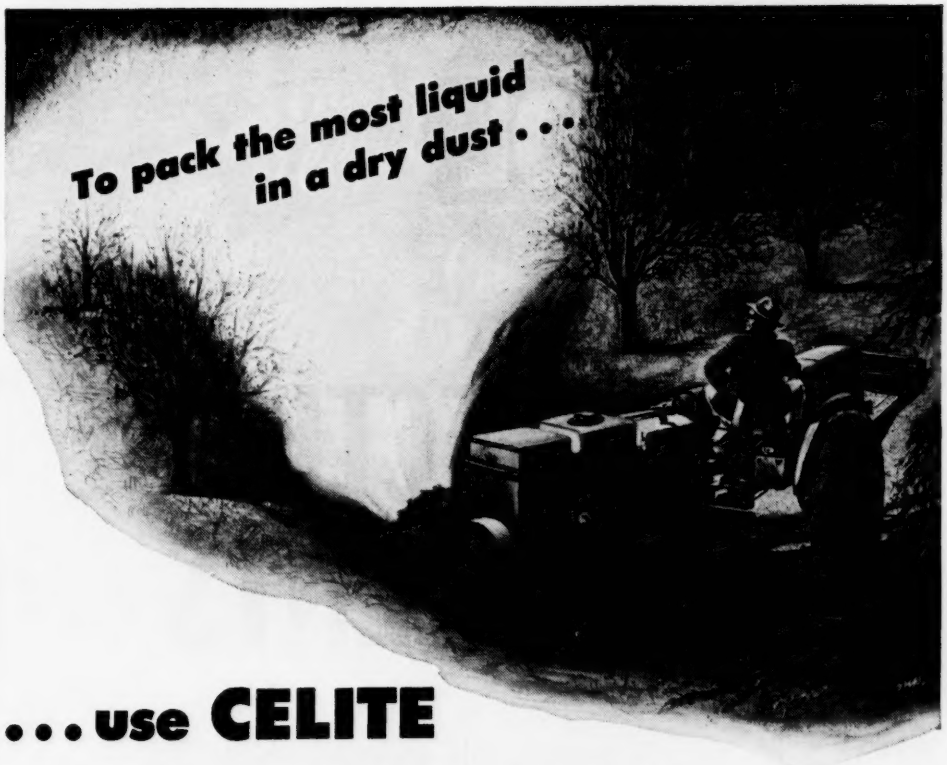

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DENSITY (Vibrated): 11 pounds per cubic foot
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ABSORPTION: 200% of its weight of water
300% of its weight of kerosene
pH VALUE: Below 7.0
INERTNESS: Compatible with insecticide and fungicide poisons
SUSPENSION: Excellent in both air and water
COMPOSITION: Celite is amorphous diatomaceous silica (SiO_2)

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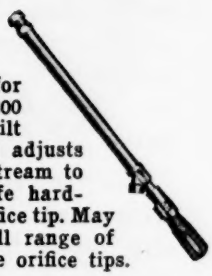

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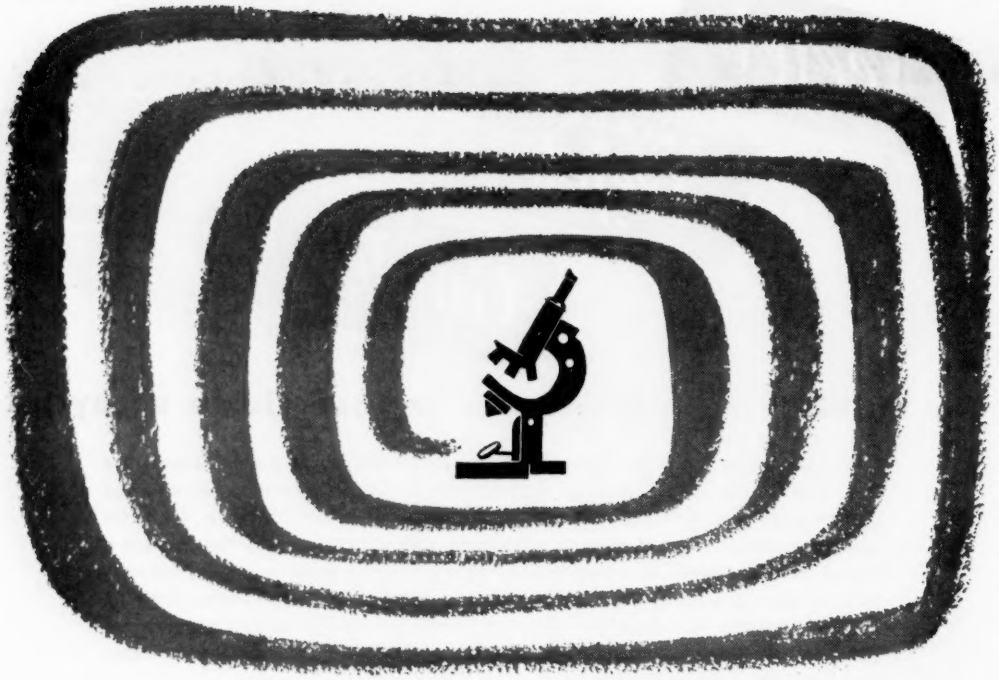

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first among growers
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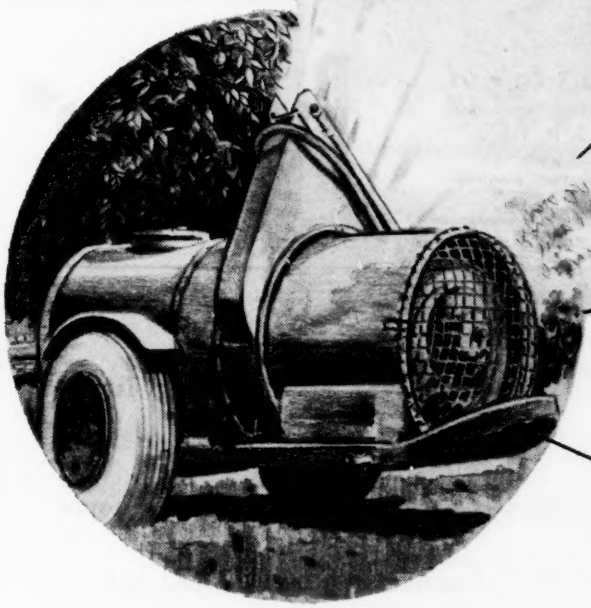

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Please note that INDEX IX for 1948-49 has not been published. It is expected that it will go to press early in 1954.

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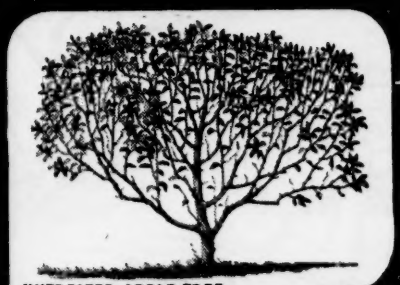

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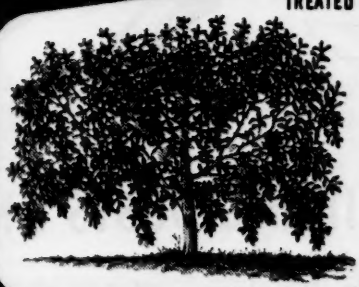

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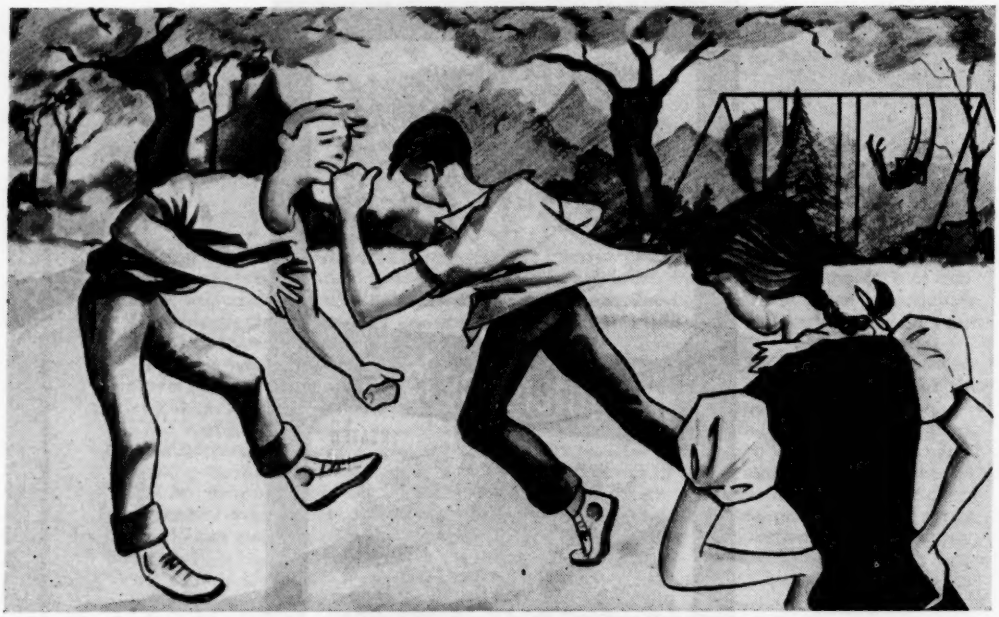

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